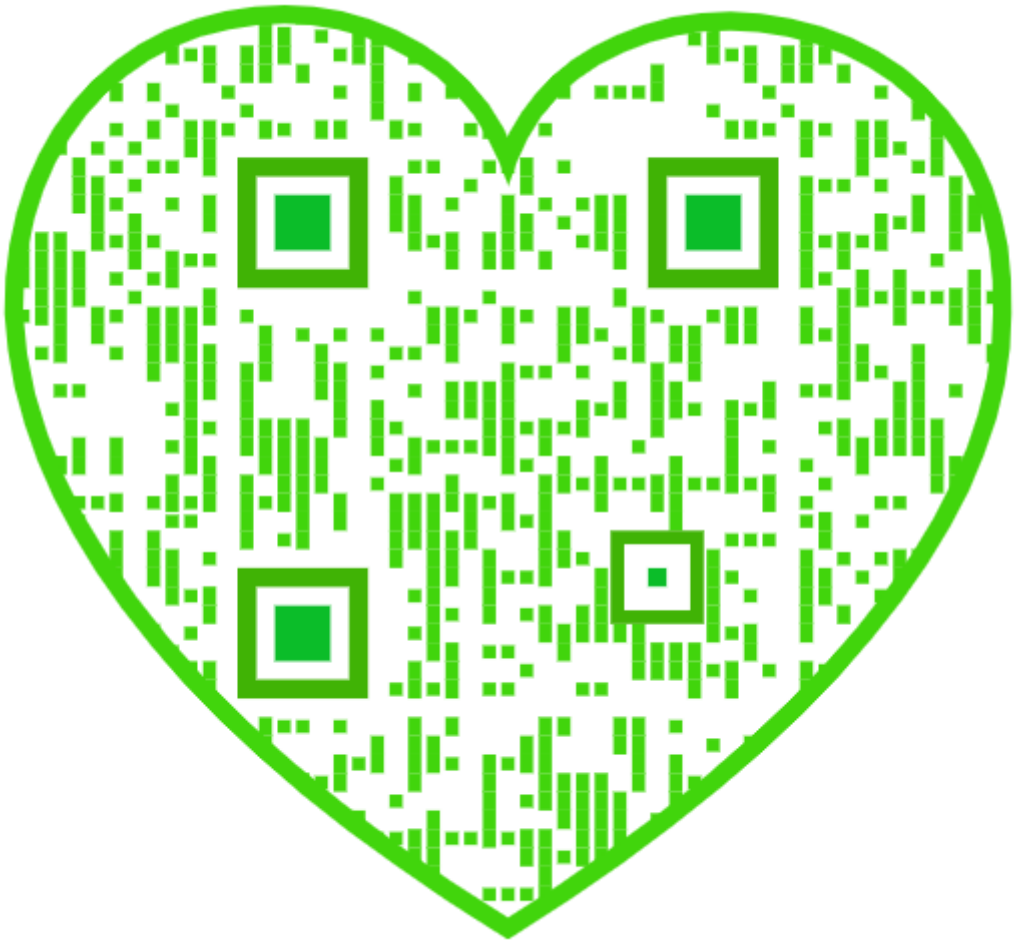

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GLUE, GELATINE,

AND THEIR ALLIED PRODUCTS.

A PRACTICAL HANDBOOK
FOR THE MANUFACTURER, AGRICULTURIST,
AND STUDENT OF TECHNOLOGY.

BY

THOMAS LAMBERT,
ANALYTICAL AND TECHNICAL CHEMIST.

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1905.

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A. I. L.

PREFACE.

THIS volume has been written with the hope that it will prove a guide and be found instructive as a work of reference to the many classes interested in the subject. The glue and gelatine industry has made an immense advance during the last few years. Old methods of working have given way to new, and this changed condition of things, due to a better scientific knowledge of the raw materials and their treatment, the author has endeavoured to show from a practical standpoint. Not only are the various sections replete with information of an up-to-date character, but each step in the manufacture is illustrated with drawings of the latest type of machinery used. To add to the value of the work, a section has been written dealing with the waste and residual matters and their value when converted into fertilisers, while another section deals exhaustively with the physical and chemical testing of the raw and finished materials.

In conclusion, the author hopes that this work will be found worthy of acceptance.

THOMAS LAMBERT.

EGREMONT, CHESHIRE,
Sept. 1905.

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GLUE, GELATINE, AND THEIR ALLIED PRODUCTS.

CHAPTER I.—HISTORICAL.

THE art of veneering, and consequently the use of glue, was known to the Egyptians as early as the time of the third Thothmes, supposed to be the Pharaoh of the Exodus. In the sculptures of Thebes is clearly pointed out the application of a piece of rare wood of a red colour to a yellow plank of sycamore; and in order to show that the yellow wood is of inferior quality, the workman is represented to have fixed his adze carelessly in a block of the same colour while engaged in applying them together. Near him are some of his tools, with a box or small chest, made of inlaid and veneered wood of various hues, and in the same part of the shop are two other men, one of whom is employed in grinding something with a stone on a slab, and the other in spreading glue with a brush.

It might perhaps be conjectured that varnish was intended to be here represented; but the appearance of the pot on the fire, the piece of glue with its concave fracture, and the workman before-mentioned applying the two pieces of wood together, satisfactorily decides the question, and attest the use of glue by the Egyptians 3300 years ago.

In Pliny's time the ancients knew the value of good glue, for he writes (as translated by Holland):

> "Great cunning there is in making strong glew,
> And in the feat of joining with it too."

During the flourishing days of the Roman empire, evidence also exists that the manufacture of glue formed one of the industrial pursuits of the Romans; while centuries later, in our own Elizabethan age, glue was known as a valuable and useful product. Shakespeare spoke in eloquent testimony to the adhesive virtues of glue when he said:

> "Go to; have your lath glued within your sheath,
> Till you know better how to handle it."
> (*Titus Andronicus*, Act ii. scene 1.)

It is, however, due to the researches in animal chemistry made during the last century that the industry has been placed on a solid basis and become recognised as an important factor in the commercial world.

Formation.—When the skins and membranous tissues, or the bones, tendons, and ligaments of animals are boiled with water, they yield a liquor which on cooling forms a jelly, and in a dried condition the jelly becomes a hard, transparent, and somewhat elastic body known as glue or gelatine, according to its colour and purity. This product is a nitrogenous substance of the albuminous class; it does not exist ready formed in the tissues, but is the result of boiling the latter in water.

How this change is effected is but imperfectly understood, though it appears to be somewhat analogous to that of starch into gum and sugar.

Constitution.—Glue or gelatine consists of two organic bodies, glutin and chondrin, the one or the other predominating according to the nature of the raw material

used. When prepared from skins, glutin is the main constituent, while bone tissues yield a product containing a large proportion of chondrin. As a cement, the former has a greater binding power than the latter, and consequently is of more value.

Glutin and its Properties.—Glutin is a yellowish, transparent, and inodorous body, and has the following composition:

	In parts per 100.
Carbon, ...	50·10
Hydrogen, ...	6·70
Nitrogen, ...	18·51
Oxygen, ...	24·69
	100·00

When immersed in cold water, glutin, while being insoluble, loses its transparency, becomes translucent, swells, and increases in weight by absorption of the water; in hot water it dissolves completely, the solution on cooling forming a jelly. This valuable property of gelatinisation is much reduced by prolonged or repeated heating. In a dry state, glutin is unaffected by the atmosphere; in solution, however, it turns sour on standing, and in an advanced stage of decomposition ammonia is evolved. Glutin is insoluble in alcohol or ether, but strong acetic acid dissolves it freely; the solution, however, loses its jellying power, but not its adhesive property. Hot nitric acid decomposes it into oxalic and saccharic acids. In a solution of glutin, nitrate of silver or chloride of gold do not precipitate the glutin, but a portion of the metal of each salt is reduced to the metallic state; sulphate of copper is not reduced. Chloride of platinum precipitates glutin from its solution in the form of brown viscous flakes which blacken on the filter, and are afterwards easily pulverised. This test Davy regards as a certain one

for the detection of glutin in solutions which are so dilute as to be unaffected by tannic acid.

Gallo-tannic and other tannic acids unite with glutin, forming a compound similar in composition to that of leather, but incapable of being used as a substitute for that material, owing to its want of structure. The white precipitate of tannate of glutin is insoluble in alcohol or ether, but soluble in a warm solution of caustic potash. It forms a hard and brittle mass on drying. Glutin in solution is not precipitated by hydrochloric or acetic acids, alum, sulphate of iron, ferrocyanide of potassium, or acetate of lead, but is rendered turbid by the addition of a small quantity of chloride of mercury. The precipitate formed re-dissolves on shaking, but becomes permanent on adding excess of the reagent.

Submitted to dry distillation, glutin yields an aqueous solution containing carbonate of ammonium, and a thick brown oil comprising, according to Watts, aniline, picoline, methylamine, tritylamine, pyridine, lutidine, and pyrrol, together with certain neutral oils not yet investigated.

Chondrin and its Properties.—Chondrin resembles glutin in many respects, and was long confounded with it. Mulder first established its separate identity. Like glutin, it does not occur ready formed in the organisms, but is prepared by boiling certain tissues with water. When dry, it is a hard horny substance, and has the following composition:

	In parts per 100.
Carbon, ...	49·92
Hydrogen, ...	6·76
Nitrogen, ...	15·65
Oxygen, ...	27·67
	100·00

On immersion in water, in which it is insoluble, chondrin increases in weight by absorption. It is also insoluble in

alcohol and ether, but in hot water it dissolves completely, the solution on cooling forming a stiff jelly. Watts states that nearly all the acids, even organic, precipitate chondrin from its aqueous solution. The precipitate formed by phosphoric, hydrochloric, nitric, or sulphuric acids, easily dissolves when excess of the acid is used, while that formed by sulphurous, pyrophosphoric, hydrofluoric, carbonic, arsenic, tartaric, citric, oxalic, lactic, or succinic acid remains permanent in presence of excess.

Chondrin, unlike glutin, is precipitated from aqueous solution by alum, sulphate of alumina, acetate and subacetate of lead, and sulphate of iron, the precipitate being soluble in excess of the reagent used. When submitted to dry distillation it yields the same products as glutin.

Chlorine forms a precipitate in a solution of chondrin resembling in composition that produced with glutin; no similar product is obtained by substituting bromine or iodine for chlorine.

Selection of Site.—The selection of a site for the factory is a matter which requires every consideration by the intending manufacturer. In the first place, the business of glue or gelatine manufacturing is an offensive business within the meaning of section 32, sub-section 1, of the Public Health Act, and sanction is thus required from the local authority before such a business can be carried on; and this sanction is withheld if it is considered that the establishment of such a works would affect the amenity of the surrounding district and the health of the resident population. Undoubtedly a smell, sometimes of a very nauseous character, does arise from the raw materials before and during treatment, but, however unpleasant it may be, no evidence exists to prove that it is unhealthy, or that it tends to increase the death-rate of the contiguous district. In face of the prejudice existing against a business of this nature, the

intending manufacturer would be well advised if he selected a site outside the boundaries of a town, so that any smell would not give cause for complaint. In the erection of the works an important matter is the ground floorage, all of which should be concreted, and connected with a suitable drainage, so that it may be kept clean by washing.

Railway Accommodation.—Railway access to the works by means of a siding is a necessity, and a canal communication also would be of service as a cheap means of receiving and dispatching raw and finished materials.

Lighting.—As gas, even if obtainable, would not be a safe illuminant in certain departments of the works—for instance, the benzene house—an installation for electric lighting is laid down in all works using the solvent process, the current being generated from machinery driven by steam, or, if available, water-power.

Water Supply.—Another very important point is the water supply. Water is used not only for the raising of steam, but also for manufacturing purposes, and to fulfil both requirements it is essential that it should be soft or only moderately hard, of good colour, and free from any decomposing animal matter. Further, the water should have no acid reaction or contain any iron likely to injure the quality of certain classes of glue. The waters having these qualities are the drainage waters from upland surfaces. They are generally very soft, owing to the fact that their mere surface contact with the soil does not lead to the extraction of any considerable quantities of the salts present in the latter, and that any organic contamination there may be is of vegetable and not animal origin, as evidenced by the small proportion of nitrogen in comparison with the carbon usually found in such waters.

If surface waters are not available, and the supply is dependent on natural spring or well waters, the latter,

although suitable for manufacturing purposes, would require a softening treatment before being used for steam-raising, owing to the scale-forming salts they invariably contain. These salts, composed of carbonate and sulphate of calcium with carbonate of magnesium, crystallise out when the water becomes saturated in the boiler, forming, especially when sulphate of calcium is present to any extent, a hard incrustation on the boiler plates, which not only causes a considerable loss of heat, but also renders the plates liable to be damaged through overheating.

The removal of these salts in the feed water is a necessary action if the boiler is to be preserved and a saving of fuel effected, and is carried out by a method of precipitation, as adopted in the several water-softening processes now in use, the reagents employed being lime and soda-ash, the former removing the temporary hardness of the water due to dissolved bi-carbonates of calcium and magnesium, while the latter decomposes the sulphate of calcium constituting the permanent hardness.

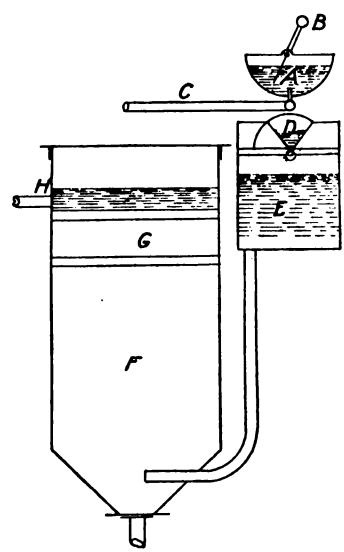


FIG. 1.—Brunn-Lowener water softener. Section.

Water Softening.—In fig. 1 is shown a section of the Brunn-Lowener continuous water-softener, as given in a very interesting report on the purification of feed waters by Mr C. E. Stromeyer, the chief engineer of the Manchester Steam Users' Association. The process is carried out by dissolving the lime and soda-ash by the aid of a steam jet in

a semi-cylindrical tank A, fitted with a blade B, which every now and then stirs up the milky mixture. The water supply from the pipe C is run into a measuring tip D, consisting of two triangular troughs; when one is full it tips over and allows the other to fill; while tipping, it moves the stirrer, and also momentarily opens a little valve at the bottom of the tank A, which allows a definite quantity of the chemicals to be discharged. This and the water from the tip D falls into the mixer E, and from there they flow into the settling tower F, the sediment remaining at the bottom; the nearly clear water passes through the filter G, and is discharged to a feed-tank through the pipe H.

The proportions of lime and soda-ash used vary according to the hardness of the water treated, some requiring only $1\frac{1}{2}$ lbs. lime and $\frac{1}{4}$ lb. soda-ash for every 1000 gallons to be softened.

Roughly speaking, the cost of a plant for treating 1000 gallons of hard water per hour would be from £150 to £200; and as 750 gallons per hour is as much as one 8-feet Lancashire boiler can evaporate, Mr Stromeyer considers that it is cheaper to adopt a water-softening process than to lay down a spare boiler if only one is in use; and even if there are six boilers, the advantage would still be with the softening plant, on account of the less cost of chemicals, which could then be used and the saving in the cost of scaling.

In laying out the works, the following ground plan (fig. 2) may be of interest. The references to the plan are given below.

a—Works' siding.
b—Storage for fresh bones.
c—Crusher.
d—Conveyor.
e—Benzene house.
f—Mechanical cleanser.
g—Acid-steeping vats.
h h h h—Lime pits for skins.
i i i—Skin washers.
j—Skin-boiling house.

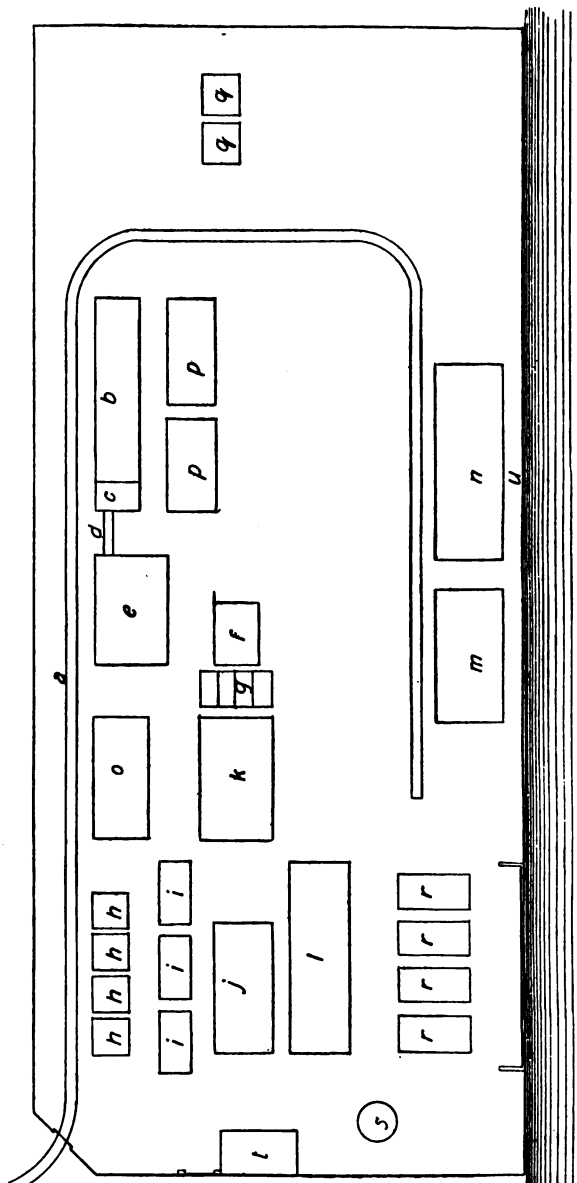


FIG. 2.—Arrangement of works. Ground plan.

k—Bone-boiling house.
l—Jellying and drying house.
m—Storage for boiled bones.
n—Warehouse.
o—Manure house.
p p—Marrow bones.
q q—Tanks for effluents.
r r r r—Steam boilers.
s—Chimney.
t—Office and laboratory.
u—Canal wharf.

CHAPTER II.—GLUE.

Formation.—When subjected to the action of heat and water, the skins and tissues of nearly every animal yield a certain proportion of glutinous matter, which on desiccation forms a hard, glassy-looking substance known as glue.

The treatment of skins with milk of lime not only dissolves the blood and epidermis, but in some way predisposes the tissue to be converted into gelatine, and this action is enhanced by the subsequent drying of the 'limed' skins. This change, however, does not result in the formation of gelatine, but only assists, the transformation into the latter body being effected by the after-process of boiling.

With bones the membranous tissue forming the ossein is identical in composition with gelatine, but, unlike the latter, is totally insoluble in water, and it is only by the action of steam or hot water that the conversion is effected into a soluble gelatine. Solutions of glutinous matter have the valuable property of jellying when cooled, and this power of gelatinisation depends, according to the late Dr Gregory, Professor of Chemistry, Edinburgh University, on the presence of small proportions of phosphate of lime, for when gelatine is long boiled with water alone, or with a little alkali, phosphate of lime is deposited, and the solution no longer forms a jelly on cooling.

Bone Glue.—The glues of commerce are classified as bone or skin glues, according to the nature of the raw materials used in their preparation, and their methods of manufacture will now be described.

Bones constitute the framework supporting the softer portions of the animal body, and are rendered stiff and rigid by earthy salts, composed mainly of phosphates of lime and magnesia and carbonate of lime. The proportions of earthy and organic matter vary with the kind of bone and the age of the animal, the bones of the adult containing more earthy salts than those of a young animal. On the other hand, the organic matter, though less in quantity in the old, has practically the same composition as that of the young animal, as is seen from the following analysis by Fremy :—

	In parts per 100.			
	Carbon.	Hydrogen.	Nitrogen.	Oxygen.
Ox (old), . .	49·81	7·14	17·32	25·67
Calf, . . .	49·90	7·30	17·20	25·60

The organic matter may be separated from the earthy salts by steeping the bones in a dilute solution of hydrochloric acid, which dissolves out the phosphates of calcium and magnesium, along with carbonate of calcium, leaving a skeleton which retains the size and form of the original bone. This substance is semi-transparent, soft, and flexible, and when dried resembles horn. On boiling in water it is converted into gelatine, with the exception of a few fibres which are insoluble and may be separated by filtration.

Degreasing of the Bones.—Bones as used in the works are delivered in a fresh condition, or as marine store bones which have generally been used for making soups. Naturally

the former yield more fat and glue than the latter. Taking an average, fresh bones comprising the heads, ribs, shoulder-blades, etc., yield 12 to 13 per cent. fat, while from the large thigh bones, known as 'marrows,' 17 to 18 per cent. is obtained.

Owing to their having been previously steamed, Indian and South American bones are poor in fatty and gelatinous matters, and are mainly used in this country for manurial purposes.

The following analyses, by the author, indicate the composition of fresh bones:—

	In parts per 100.	
Moisture, ...	11·55	12·88
Fat, ...	12·69	12·42
Organic matter other than fat, ...	21·64	21·29
Phosphates of calcium and magnesium, . . .	47·83	48·66
Carbonate of calcium, .	3·14	2·74
Alkaline salts, . . .	2·67	1·72
Silica, etc., ...	·48	·29
	100·00	100·00

Of these constituents, the fat is used in the manufacture of soap, glycerine, and other products; the organic matter other than fat furnishes glue and gelatine, while the phosphates form the basis of artificial manures.

The first stage in the treatment of bones is the extraction of the fat, the yield of which varies according to the method employed. The degreasing can be carried out (1) by open boiling of the bones in a wooden vat provided with a steam coil; (2) by digestion under steam at 40 lbs. pressure; and (3) by solvents. The yield of fat by the first process is low, averaging only 5 per cent.; by the second, this amount is

increased to 7½ per cent., with the removal of a large portion of the gelatinous matter; while by the adoption of the third method, practically the whole of the fat is obtained, leaving the tissues unimpaired for subsequent conversion into glue.

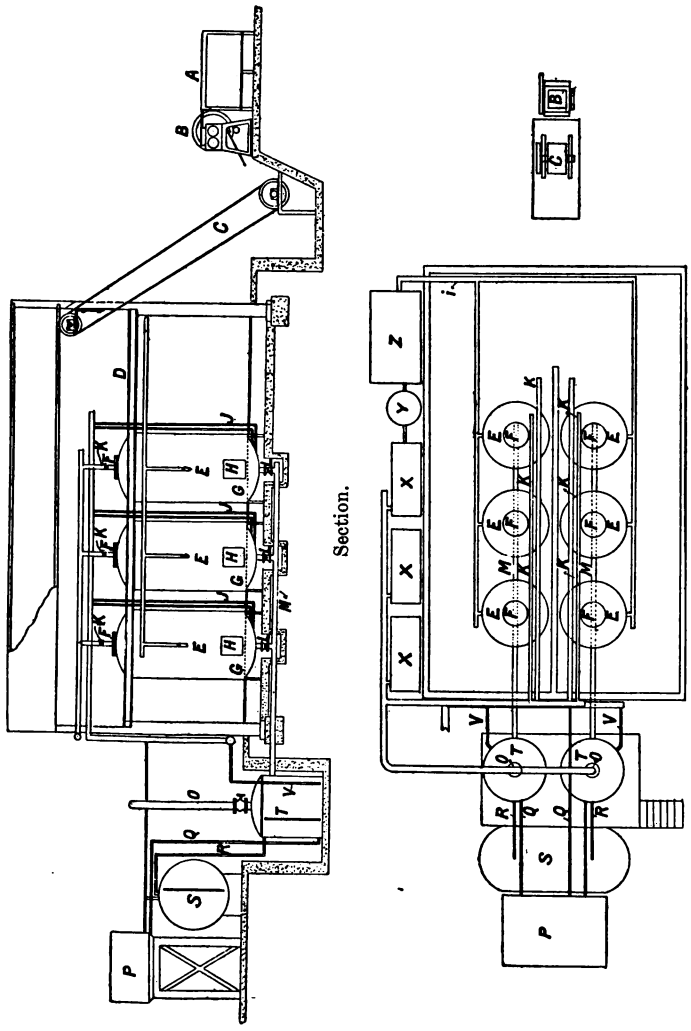
On a working of 100 tons fresh bones the money value of the fat recovered, based on a value of £25 per ton, would be with—

(1) Open boiling, . . .	£125
(2) Steaming under pressure, .	£187, 10s.
(3) Solvents, ...	£312, 10s.

As is well known to chemists, animal and vegetable fats are soluble in ether, alcohol, benzene, petroleum, bisulphide of carbon, and other solvents, and on this property is based the system of extraction which is now superseding the old methods of open boiling or steaming (under pressure) the fresh bones. Of these agents ether and alcohol are used mainly for laboratory determinations of fat, while bisulphide of carbon, though an excellent solvent, is found unsuitable in working, from its low volatility. In practice the best solvents are found to be Scotch shale spirit and American or Russian petroleum, with boiling points at or about 212° F. and distilling completely over between 270° F. and 280° F.

In fig. 3 is seen a section, and in fig. 4 a plan, of a modern installation for the degreasing of bones. The main building contains six extractors, each of five tons capacity, and their working is so arranged that while half their number are under the action of the solvent, the other half are being emptied of the degreased bones preparatory to re-charging.

On delivery to the works, the bones are shovelled on to a sorting table A, and the hoofs, horns, and any pieces of iron,



FIGS. 3 and 4.—Benzene plant for degreasing bones. Section and plan.

wood, etc., removed. From thence they pass through the mill B, which slightly cracks them, to the elevator C, and are discharged on the upper floor D of the extracting house. Each of the extractors E is provided with charging, F, and discharging, H, manholes, and has a false bottom G, under which rest the dry and wet steam coils supplied from the pipes J in connection with the main steam pipe. At the top of each extractor is fixed the outlet pipe K for conveying the solvent and steam vapours to the condensers X X X, which are placed at an elevation outside the main building. After condensation, the solvent and water flow into the receiver Y, where the former, from its lighter gravity, separates from the water and is run into the storage tank Z, from whence the supply to each extractor is brought through the pipe I. All the pipes are supplied with the necessary valves and cocks.

On the extractors receiving their full complement of bones, the charging manholes are securely fastened and the first run of solvent is made to a depth of 2 feet, as measured in the gauge-glass fixed to each extractor, and heat gradually applied through the dry steam coils. As the operation proceeds, the solvent is gradually distilled over, carrying with it the moisture mechanically held by the bones, and at a point when it becomes but barely visible in the glass, the steam through the dry coils is shut off, the discharge valves L L L opened, and the first charge of extracted fat is run through the pipe M to the montejus or distiller. This action is repeated with a second, third, and fourth run of solvent from the storage tank, the fat left at the end of each action being run to the mont-jus as before. With the finish of the fourth charge of solvent the bones are found to be practically deprived of their fat. They still, however, retain a portion of the solvent, and to recover this, the wet steam valve is opened and high-pressure steam (70 to 80 lbs.) blown through

the mass of bones until the faintest film of solvent only is seen separating from the condensed water running into the receiver.

The operation, which has taken from eleven to twelve hours, is finished with the closing of all valves and the removal of the manhole doors to facilitate the escaping steam, and to dry the bones, which are then raked out and conveyed by a railway to the cleanser, and from thence to the glue-boiling house. The degreased bones are in a dry condition, free from smell, and retain on an average only ·2 per cent. of fat on being withdrawn from the extractors.

In the meantime, the crude fat is receiving attention in the mont-jus. As it leaves the extractors, it retains a portion of the solvent along with dirt and mineral matter, and it is the object of the second distillation to recover this solvent, the other impurities being removed by a subsequent washing which the fat receives.

The mont-jus T is a still heated by the steam pipe V, and is provided with an outlet pipe O, through which are conveyed the solvent vapours to the main pipe of the condensers. On the mass being brought to the boil, the solvent vapours pass freely over and the heat is continued for about two hours, at the end of which time the fat will retain only a faint smell of the solvent, while the film at the receiver will be but barely visible. These results being attained, the main valve is closed and hot water run in through the pipe Q from the cistern P, heated by a connection from the main steam pipe. As the water flows in the fat is floated through the pipe R, the valve of which has been opened, to the washer S, where it undergoes a boiling with water for three hours, the aim being to deposit the dirt and mineral matter and leave a clean fat, which is floated off by means of hot water, the stream of fat being distributed by pipes into a number of casks conveniently placed for filling.

Analyses of Finished Fat.—The following analyses, by the author, represent the composition of the finished fat:—

		In parts per 100.	
Moisture, . .	1·181	·732	1·406
Naphtha, . .	·031	·008	·005
Ash (mineral matter),	·169	·121	·287
Organic matter other than fat,	·072	·093	·136
Fat, . . .	98·547	99·046	98·166
	100·000	100·000	100·000

Fat extracted by solvents is darker in colour than that produced by boiling or steaming the bones. The colour, however, can be brought up to a good white by bleaching. It is bought on a basis of 98 per cent., a limit of 2 per cent. being allowed for moisture and other impurities. In order to improve the colour of the fatty and gelatinous matter of the bone, some manufacturers, prior to the benzene treatment, bleach the raw material by immersion in a very dilute solution of sulphurous acid. As presently carried out, the degreasing by solvents and the subsequent degelatinisation of the bones after cleansing, form three operations which are costly to the manufacturer, from the frequent handling of the material and the heavy consumption of steam. To reduce this cost attempts have been made to combine the degreasing and degelatinising of the bones in one operation, and thus dispense with the cleansing process. To this end, tetrachloride of carbon, and also the mixed vapours of benzene and steam acting in a battery of extractors working together, have been suggested. Unfortunately, while the extraction of fat is up to the standard, the resulting gelatinous liquor fails to yield a clear and bright glue.

The process of cleansing has for its object the removal of loosely adhering dirt and fleshy matter, and is carried out in a

large cylindrical drum A (fig. 5), measuring 14 feet in length by 7 feet in diameter, horizontally working on a central shaft. The drum is open at both ends, and covered with a stout wire gauze. At the charging end B the degreased bones are fed through a hopper C, and as the drum slowly revolves they undergo a polishing action by friction, the detached mineral and organic matter falling through the meshes of the wire gauze into a chamber D below. From

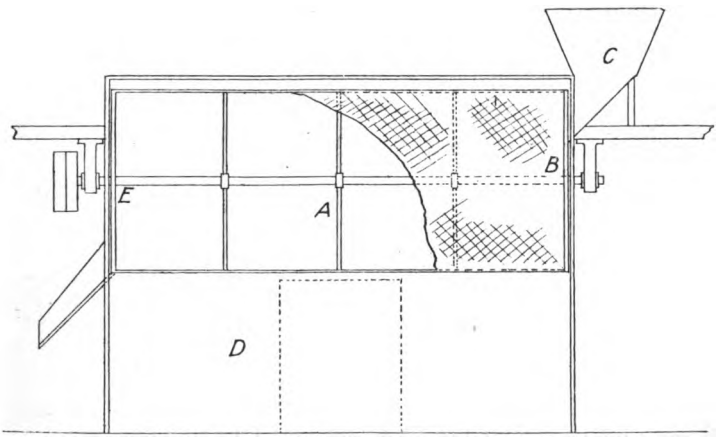


FIG. 5.—Mechanical cleanser. Longitudinal section.

the discharging end E the cleansed bones are conveyed to the acid steeping vats for gelatine making, or to the glue house.

As is seen from the following analyses by the author,

	Per cent.	Per cent.	Per cent.
Nitrogen, . .	5·29	6·08	5·72
Phosphate of lime,	28·11	27·43	30·66

the coarse meal passing through the meshes of the cleanser contains a high percentage of nitrogen, which, however, is not wholly derived from the bone itself, but partly has its origin in the hair of skins connected to the bone, or passing

in a loose state into the extractor. In the former condition only is the nitrogen of a glue-forming nature, and to recover it the coarse meal is passed through a smaller revolving cleanser, covered with a 30-mesh wire. Here fully half the weight is separated, and as it leaves the discharging end of the cleanser is bagged and passed on to the glue house for further treatment.

The dust or flour falling through the netting is sold as a low-grade bone meal, or used in the mixings of the manure house.

The following yields are taken from the returns of several runnings made with raw bones:—

Raw Bones taken.				Grease.				Degreased Bones before Cleansing.				Cleansed Bones for Glue House.				Bone Meal.		
t.	c.	qrs.	lbs.	t.	c.	qrs.	lbs.	t.	c.	qrs.	lbs.	t.	c.	qrs.	lbs.	c.	qrs.	lbs.
8	7	0	21	1	1	2	5	4	18	3	12	4	11	3	4	7	0	8
8	11	3	17	1	2	0	0	5	1	2	26	4	17	0	24	4	2	2
9	0	0	0	1	4	3	1	5	6	3	7	5	0	2	3	6	1	4

When in a condition ready for glue-making the cleansed bones contain 5 to 6 per cent. of glue-forming nitrogen and 58 to 62 per cent. of phosphate of lime.

CHAPTER III.—GLUE (*continued*).

As previously remarked, glue does not exist ready formed in nature, but is the product of heat on nitrogenous animal tissues, and this work, as carried on in the boiling house, requires the exercise of much knowledge and skill on the part of those engaged in it. The operations of the boiling house may be divided into (*a*) Conversion of the tissues into a glue liquor by steam and water; (*b*) clarification; (*c*) concentration; (*d*) bleaching.

With steam and water alternately playing on the bones, or by the action of direct steam, the extraction is made in large boilers, built of steel plates $\frac{3}{8}$ in. thick and holding from three to five tons according to the method used. By the adoption of the first, the boilers A A are worked in couples as seen in elevation, fig. 6. The glue liquors are, however, bulky, and low in strength, which renders them troublesome in clarification and costly in concentration. For these reasons many manufacturers prefer the second or direct steam method as a more economical process of extraction. In fig. 7 is represented a section of a boiling house working with direct steam and illustrating the arrangement of boilers, clarifiers, etc, the ground and first floors being shown in part in the plan, fig. 8. Each boiler A is fitted with a false bottom B and provided with charging and discharging man-

holes C D. A steam gauge E is also attached to regulate the pressure of steam, which enters the extractor by the pipe F in connection with the main steam pipe G. The cleansed bones are raised to the first floor of the boiling house by an elevator, and after charging each boiler, the steam is turned on and kept at a pressure of 15 lbs. for two hours, and then

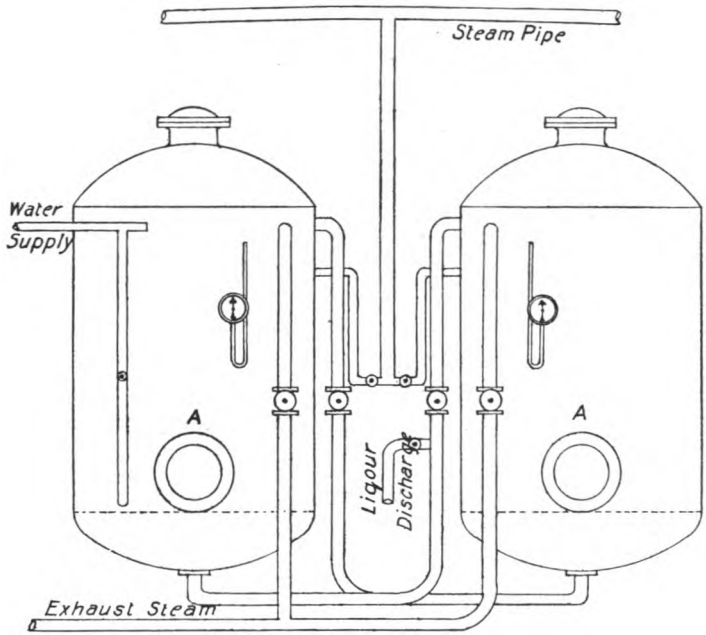


FIG. 6.—Coupled glue extractors. Elevation.

reduced to 5 lbs. This lowering of the pressure enables the glue formed within the bone to come to the surface, and is washed down by a spray of water from a coil fixed in the dome of the boiler. The action is repeated until a sample, on being tested by the glue meter, indicates a strength of about 20 per cent. dry glue. When this density is attained a first discharge is made to the clarifiers placed on the first

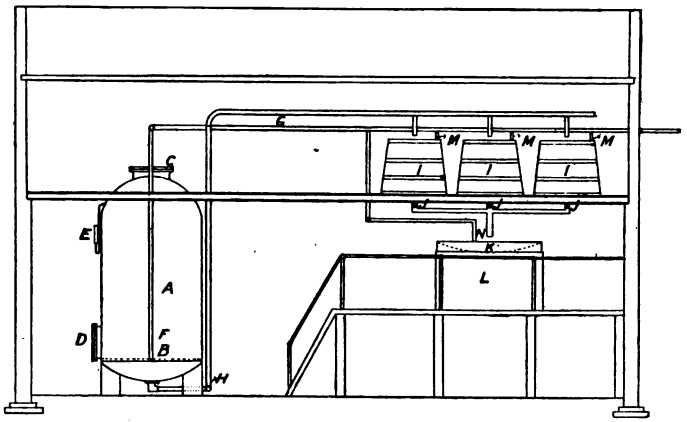


FIG. 7.—Glue boiling and clarifying house. Section.

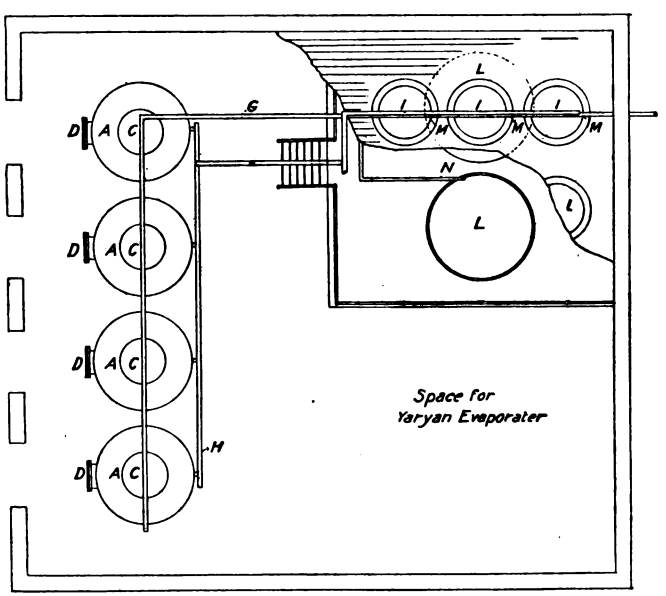


FIG. 8.—Glue boiling and clarifying house. Part of plan. Ground and first floor.

floor, as shown in section and plan, by opening the valve of each outlet pipe H and blowing the liquors to the vats I.

Taking the average, degreased and cleansed bones are capable of yielding over two-fifths of their weight of glue, and in the first run to the clarifiers the extraction will be from 65 to 70 per cent. of this quantity. The remainder, with the exception of about 4 per cent. which is practically irrecoverable, is obtained by a second steaming of the bones, the liquors being forced up to the clarifiers by steam pressure.

It will be readily understood that these liquors are far from being pure, and for the production of high-grade glues they require to undergo a process of clarification.

Although many ingredients have been proposed for clarifying glue liquors, as oxalic acid, phosphate of soda, basic acetate of lead, blood, etc., nothing as yet suggested fulfils the purpose to better advantage than potash alum, when used in the proportion half per cent. of the weight of dry glue present in the liquors. In the application, a bucketful of the liquor, which should have a temperature of about 80° C., is drawn from each vat, the necessary quantity of alum stirred in, and the contents thoroughly mixed in the mass, the heat at the same time being raised to 100° C. by means of a steam pipe M. After boiling for ten minutes the steam is turned off and the liquor allowed to settle, during which the heavier mineral and organic impurities fall to the bottom, while the lighter form a coagulated scum on the surface. These impurities are separated by filtration; for this purpose the valve J of each vat is opened and the liquors allowed to flow to the filters made of fine wire gauze or medium woven calico fixed on to a wooden framework. The two filters K K, one of which is shown in section, fig. 7, are placed over the receivers or storage vats L L, into which flow the filtered liquors, the heat being maintained by the

steam pipe N. Clarified glue solutions are never jellied below a strength of 32 per cent. dry glue in winter and 35 per cent. in summer; and to remove the excess of water necessary to obtain the density required, they undergo a process of concentration by passing them through an evaporator.

The utility of evaporating apparatus in connection with modern manufacturing processes is now widely recognised, and this recognition is fully shared by those engaged in the glue and gelatine industry.

As is well known, gelatinous solutions undergoing concentration are very susceptible to change by prolonged boiling at the normal atmospheric pressure, and consequently the evaporation of these liquors in open vessels at a temperature of 100° C. always yield a dark-coloured and inferior product.

To remedy this, advantage has been taken of the fact that the boiling point of a liquid depends upon the atmospheric pressure exerted on its surface, and if this pressure is reduced the boiling point is lowered accordingly.

For instance, at the sea-level the boiling point of water is 100° C. under an atmospheric pressure of 15 lbs. on every square inch of water surface. If, however, this pressure is reduced by mechanical means to, say, 9 lbs., the boiling point is lowered to 85·7° C., while at 3 lbs. pressure it falls to 60° C.

On this principle is based the vacuum pan, first introduced by Howard, and its more modern application is seen in the well-known Yaryan type of evaporator invented by Mr Homer T. Yaryan of Toledo, Ohio, U.S.A. The vacuum pan is of a globular form, and built of wrought iron or steel plates. It is heated by a steam jacket encircling the lower part of the pan, and by a coil of piping immersed in the liquid. At the top is fixed the dome fitted with baffle-plates, to which is connected the condenser and vacuum pump. The

pan is further provided with a steam and also with a vacuum gauge, and the concentrated liquors are discharged through an outlet valve fixed to the bottom.

The vacuum pan cannot be considered an economical method of evaporating a liquor, for, although a large amount of work may be performed per square foot of heating surface, yet for every pound of water evaporated out of the liquid under treatment, an equal weight of steam—or more, according to the initial temperature of the liquor—is produced having the latent heat of the original steam, which, though capable of doing useful work, passes directly to the condenser, there to be uselessly absorbed by the condensing water.

Now if this steam were conducted to the jacket and coil of a second pan working under slight vacuum it would generate nearly its own weight of steam at a lower pressure and temperature, and so evaporate the water from the second pan. This steam would be available for a third pan, and the service may be continued until the original heat of the steam is wasted by radiation and other causes.

This is the principle of the double and multiple effects as used in the Yaryan type of evaporator, and its economical advantage is noticed in the fact that for every pound of coal consumed in the boiler fire to generate steam for the jacket and coil of the vacuum pan only 8 lbs. of water are evaporated from a glue liquor, while in the double effect 16 lbs. are evaporated for the same consumption of fuel, and 23½ lbs. in the triple effect.

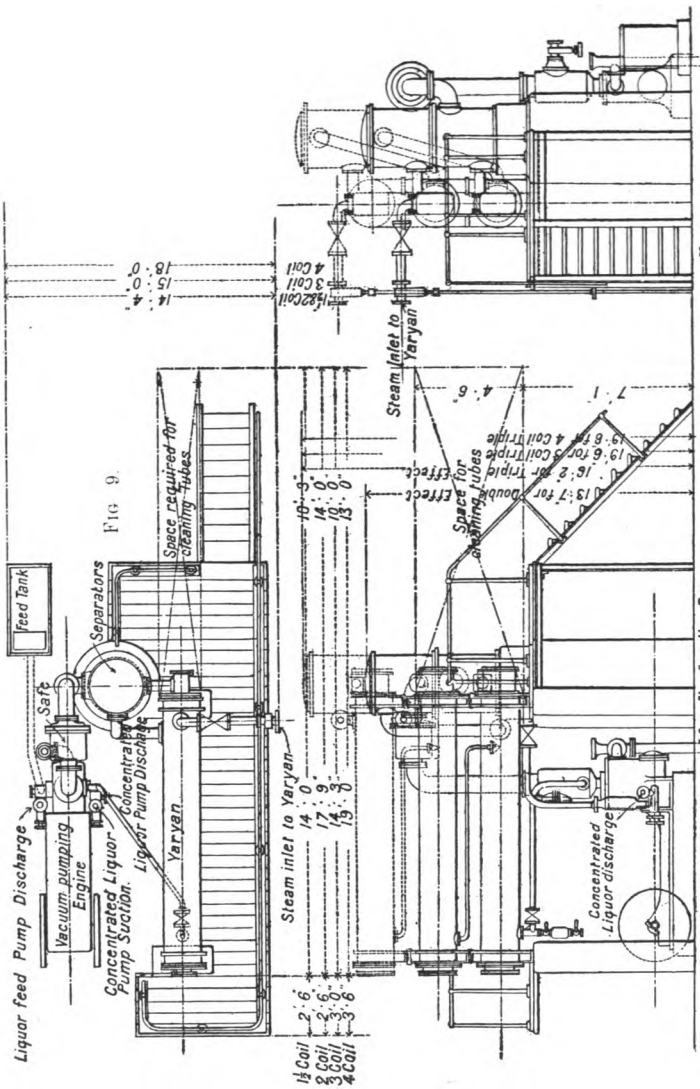
A further advantage claimed by the Yaryan is the limited time the glue liquors are under heat, only three minutes elapsing from the time of entering the machine to their delivery at a strength ready for jellying. This short duration of heat exposure is an important consideration in the after-production of a good cake of glue.

Through the courtesy of the makers, Messrs The Mirrlees

Watson Company, Ltd., engineers and founders, Glasgow, the author is enabled to give a complete drawing of the Yaryan, which is now extensively used in the concentration of glue liquors. In figs. 9, 10, and 11 are shown the plan, front elevation and end elevation respectively, of the machine.

The Yaryan consists of two or more horizontally placed cylinders forming the double, triple, or multiple effect as required. Each cylinder contains a series of tubes heated by steam, the first one only by original steam. The tubes are coupled at the ends, and are divided into sections termed coils. Thus a continuous passage exists from end to end. As the glue liquor is pumped in at the inlet in a thin stream it undergoes the initial stage of evaporation, the liquid and vapour travelling from section to section, and so come into contact with the whole heating surface of the tubes. Moving at a high velocity, owing to the steam generated, the liquor and vapour on issuing from the last tube pass by a pipe to the separator, from which the steam escapes by a connection to the 'safe' or 'catch-all.'

This vessel encloses a number of tubes through which the steam travels, then impinges on the end of the vessel, and there deposits any liquid it may carry. From the separator the liquor is discharged by a branch pipe to the second Yaryan or cylinder, which is heated by the steam from the 'safe.' In a triple effect (as shown by dotted lines in the drawing) or a multiple effect, the steam generated in the second Yaryan is used for heating the third, in the manner described above, and this in turn supplies the steam to the fourth effect, and so on; from the last separator in the series, it is condensed by passing through a condenser. As will be noticed in the drawing, each Yaryan is worked under a vacuum, the object being to secure the low temperature only obtainable by this means.



FIGS. 9, 10, 11.—Yaryan evaporator. Plan, front elevation, and end elevation.

The apparatus, the double effect of which is most suitable for evaporating glue liquors (owing to the lower steam pressure at which it is worked), is easy of installation, and is readily adaptable to the exigencies of space in a glue house, for the cylinders can be arranged one above another, or horizontally side by side without affecting their efficiency. Colour being an important matter in the selling of glue or gelatine, the concentrated liquors now undergo a process of bleaching by means of sulphurous acid. Some manufacturers bleach during the clarification process, but it is preferable to do so after concentration. Sulphurous acid is applied either as a solution or in the gaseous form; the latter, however, is more economical for use and can be better regulated in the obtaining of any desired shade of colour.

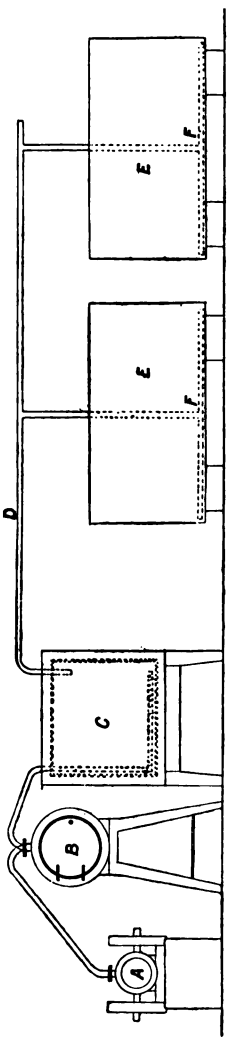


FIG. 12.—Sulphurous acid generator. Longitudinal section.

Fig. 12 represents a longitudinal section of the sulphurous acid generator, along with the tanks in which the bleaching of the liquors delivered by the discharge pump of the Yaryan apparatus is effected. A is the air-compressing engine throwing a current of air into the iron cylinder B, in which is placed a tray containing ignited sulphur. This substance burns to sulphurous acid by means of the oxygen of the air blown in, and the gas is then washed by

forcing it through the lead-lined washer C. After bubbling through the water, it is conveyed by the pipe D to the tanks E E, and delivered to the liquors by means of a coil of perforated piping F F, arranged in a manner similar to the shape of a gridiron. Each tank is also provided with a dry steam coil to prevent any cooling action during the bleaching. The progress of the bleaching is readily ascertained by withdrawing a sample, and setting it aside for a few minutes to cool; when the formed jelly corresponds in colour to the shade required, the action is stopped.

The concentrated and bleached liquors are now ready for jellying, and to effect the congelation they are run into galvanised sheet-iron troughs, having a length of 2 feet, a width of 6 inches, and a depth of 5 inches, and allowed to stand for twelve hours in a cool and dry place. Having become a firm jelly, the tremulous mass is removed, either by cutting round the edges with a knife and then overturning the trough, or by slightly warming the latter in hot water, which by softening the outer portion of the jelly, easily allows of its removal on turning the trough over.

Although mechanical means have been devised, of which may be mentioned the Schneible machine, to cut the blocks into cakes of the size and thickness desired, they have but a very limited use in this country, as manufacturers generally prefer to use the 'wire knife,' which gives to the cakes the wavy appearance desired in cut glue, and which is not obtained by a glue-slicing machine. In cutting in this way, the jelly block is placed in a wooden box open to the back in several slits or divisions, of a size corresponding to the thickness which the cakes of glue are required to have. It is then cut into slices by passing a brass wire stretched in a frame like that of a bow-saw along the slits. On removal of the sides of the box, the sliced block of jelly is cut with a wet knife into divisions representing the size of the cakes

desired. Cutting by wire is effected in some Continental glue works by a machine, and an ingenious contrivance used for this purpose is represented in section in fig. 13. A is a platen which is raised by the ram B, worked by water power. The platen forms the bottom of a chamber C, D D being the ends, while the top E is a hinged framework of wood, on which are stretched the cutting wires F. In the chamber, and resting on the platen, is placed the glue block,

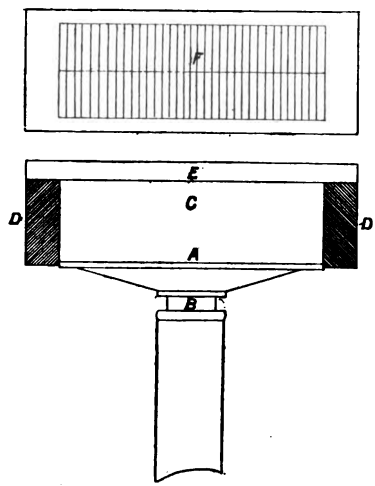


FIG. 13.—Hydraulic glue cutter. Before cutting. Section.

and on raising the platen by hydraulic pressure, it is forced through the wires, which slice it into cakes ready for drying. Fig. 14 illustrates the position of the platen and glue block after cutting.

The larger proportion of glue brought into the market is in the form of cast glue. In producing it, the cooling troughs are dispensed with, the liquors being jellied in sheets on glass slabs fixed on long rows of oblong tables A, figs. 17 and 18. Between the bottom of the glass and the top of the

table a constant flow of cold water is allowed to run for the purpose of better congealing the glue solutions which cover the slabs to a depth of from one quarter to one-half inch, according to the thickness desired.

At the Gorgie Works of Messrs Cox, Limited, Edinburgh, the glass slabs are fed from small round cylinders, which carry the glutinous liquors by means of an overhead railway suspended from the ceiling. When stiffened to a proper

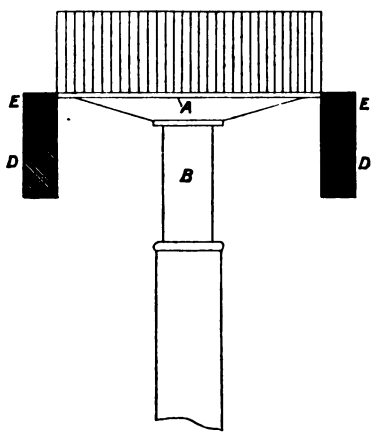


FIG. 14.—Hydraulic glue cutter. After cutting. Section.

consistency, the jellied sheets are cut with a wet knife into small cakes of the size required.

The drying of the jelly is a very important stage in the manufacture of a cake of glue, and although, in the modern method of desiccation, the difficulties which attended open-air drying, and which limited the work to temperate and equable weather, are largely surmounted, yet the process requires very great care if a good and saleable product is to be obtained. Glue in a jellied condition is not capable of withstanding a higher temperature than 25·5° C.; above this it softens and becomes unshapely, so much so as to run

through the nets, or get attached to the strings, and surround them, so as not to be separable without the use of hot water. In hot weather, therefore, the air is cooled by passage through a refrigerator before coming into contact with the congealed cakes. On the other hand, the air in winter is too low in temperature to be effective as a drying agent, and in addition is generally so humid that the moisture on condensation would occasion a mouldiness on the surfaces of the cakes. For winter work, then, it becomes necessary to reverse the conditions of summer drying, by warming instead of cooling the air, and this is effected by passing it between a

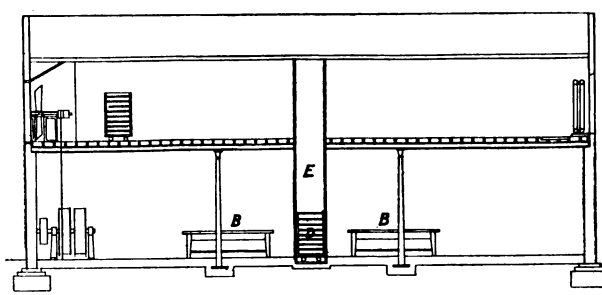


FIG. 15.—Drying house. Longitudinal section.

series of 6-inch pipes, heated by waste steam, before entering the drying chambers.

Fig. 15 represents a longitudinal section, fig. 18 a cross-section, and figs. 16 and 17 the first and ground floors respectively, of a modern drying-house. Whether the glue liquors are jellied in troughs or cast on glass slabs, the congealing is carried out on the ground floor, which in summer is kept cool by a refrigerator (not shown in the drawings).

Here also are placed the cutting tables B B, or the cutting machine, if one is used, as seen in figs. 13 and 14, and the engine C, driving the exhaust fans above. On this floor the cut or cast cakes of jelly are lifted on to frames, 4 feet

in length by 2 feet in width, formed of netting stretched on a wooden framework, and these are built up on a bogie forming a rack D, which enables the cakes to be equally

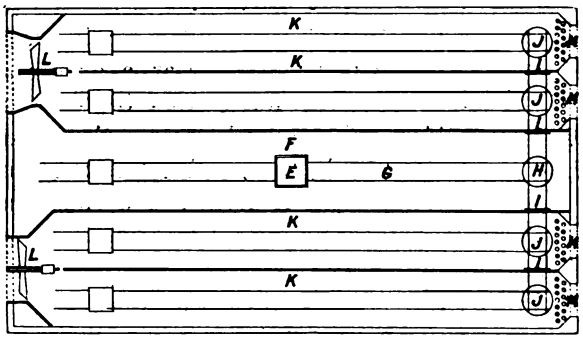


FIG. 16.—Drying house. First floor plan.

exposed to the action of the air. The rack is raised by the hoist E to the first or drying floor.

As will be noticed in the plan, fig. 16, and the section,

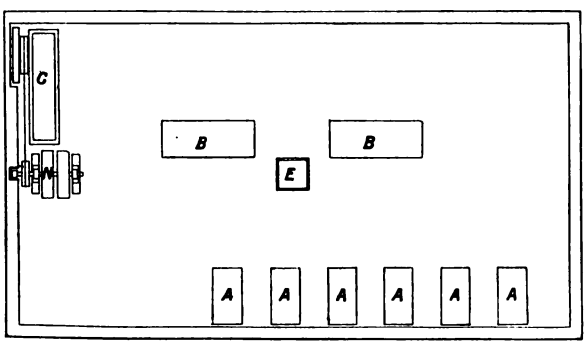


FIG. 17.—Drying house. Ground floor plan.

fig. 18, this floor is partitioned into three main divisions running the length of the building, the two outer being further subdivided into chambers or tunnels K K K K. M M M M are the steam pipes heating (in winter) the air

before its passage through the chambers, and L L the fans, actuated from the countershaft N. Access is gained to the chambers through the sliding doors I I I I.

In the central division F the glue racks are received from the hoist E and conveyed over the tramway G to the turntable H, passing thence to the chambers on the right or left by the turntables J J J J. When the chambers are filled, the doors are closed and the fans set in motion. At the maximum speed, the strength of the current may be judged from the fact that 20,000 cubic feet of air are drawn through each chamber every minute, and in passing over the frames,

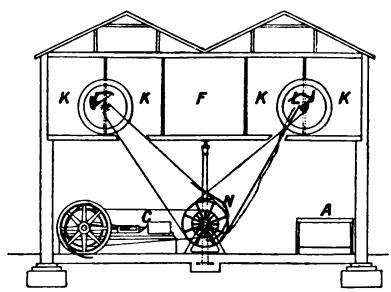


FIG. 18.—Drying house. Cross-section.

absorbs the water of the jellied cakes without unduly preventing their contraction to the proper size.

The temperature of the current is noted by Centigrade thermometers conveniently placed in each chamber, while its humidity is recorded by dry- and wet-bulb hygrometers. The drying, which occupies from four to five days, is carried on continuously, and finally yields a hard and solid product retaining from 10 to 13 per cent. moisture. When this end is attained, the racks are removed from the chambers, and the dried cakes conveyed to the warehouse *n* (fig. 2) to be sorted and then carefully packed in bags, barrels, or tin-lined boxes.

CHAPTER IV.—GLUE (*continued*).

Skin Glue.—Nothing in the industrial world is more indicative of progress than the utilisation of wastes or residues from manufacturing operations, and an evidence of this progress is seen in the establishment of a great industry largely dependent for its raw material on the wastes produced in the treatment of ox, calf, sheep, and other skins.

The skins of animals consist of two layers: (1) the outer, in which the hairs are developed, certain sudoriferous and sebaceous glands, and is known as the *epidermis*; (2) the inner layer, called the *corium*. The epidermis, though soluble by prolonged immersion in boiling water under pressure, does not yield a gelatinisable liquor; on the other hand, the fibrous connective tissue, which forms nearly 95 per cent. of the corium, is wholly soluble in boiling water, and yields a liquor having the property of gelatinisation on cooling. By treating the corium with any of the vegetable tannins, as in the process of tanning, the well-known substance leather is produced, this product being chemically a tannate of gelatine.

The raw materials of the glue-maker form a surprisingly heterogeneous collection. Such things as the clippings of hides, ear and tail pieces of ox, calf, and sheep, rabbit skins, scraps of parchment, and many other apparently worthless things, all contribute their quota.

The hides as brought into the market are classified into oxen, ranging in weight from 53 to 93 lbs., cows, bulls, cut bulls, heavy cuts, medium cuts, light cuts, salted Irish hides and kips, horse, etc.; while the lighter skins are arranged as calf, damaged calf, kips, wool, Scotch lamb, pelts, etc.

Previous to the tanning process with the extracts of valonia, myrabolans, divi-divi, gambier, quebracho wood, and other barks, the hides and skins are limed and unhaired in the usual way, and then subjected to a clipping process which removes the tail, head and ear pieces, parts which, though useless for leather-making, form valuable raw material for the glue-maker. A fine quality of glue is also produced from the residues in the manufacture of kid gloves. The raw skins are prepared by immersion in milk of lime for from two to three weeks. The skins are constantly turned and shifted about by workmen armed with long iron tongs, and when taken out of the pits, it is found that the lime has loosened the cuticle of the skins, thus rendering the removal of the hair a more easy matter. From the lime pits the skins are taken to the unhairing room, where they are stretched on a wooden block and scraped with a blunt two-handled knife. They are now taken in hand by the 'flesher,' who cuts off the tail, the head piece, and the portions of adipose matter which may still adhere to the skins. The waste pieces are in great demand by the glue-maker, the hair being used for mortar and for felt-making.

The range of raw materials used by the glue-maker would be much extended if leather waste could be used in the manufacture. Leather is a tannate of gelatine, and the attempts at separating the two constituents so as to render the gelatine available for glue-making has not met with any practical success. According to Mulder, it appears that several definite and permanent combinations of gelatine with tannic acid are capable of being formed. On commingling

the pure solutions of these bodies, a neutral combination containing one equivalent of gelatine, one of tannic acid, and two of water, is formed. From the investigations of Davy, the compound of gelatine with oak-tannin consists of—

	In parts per 100.
Gelatine, ...	54
Tannic acid, ...	46

When leather is acted upon by a dilute solution of ammonia, much of the tannic acid is extracted, and there is left a gelatiniform, mucilaginous, swollen mass, which, with the aid of heat, dissolves like gelatine; but it is found that the solvent employed for removing the tannic acid has also taken up a certain quantity of gelatine; if the mass in question be digested with water, a little of the gelatine dissolves out, while the remainder is converted into a combination of gelatine and tannin which is precipitated with extreme slowness.

In the manufacture of high-class glues, much discretion is required in blending the various waste products from the tannery, and experience has shown that a mixture of hide, ear, and face clippings from the ox and calf yields the best glue. At the Gorgie Mills of Messrs Cox, Edinburgh, the raw material is classified into three great divisions for the purpose of manufacture, viz.: (1) sheep pieces and fleshings; (2) ox fleshings and trimmings; (3) ox hides and pieces.

The first stage the raw material, or 'stock,' as it is technically termed, undergoes in the glue work is a steeping in milk of lime, which removes any adhering dirt and dissolves the blood and fleshy matter, in addition to acting as an antiseptic in preserving the stock, if it is not to be immediately employed. The 'liming' is carried out in large wooden vats some 10 feet square and 4 feet deep; or in pits of the same dimensions, built into the ground and

lined with a coating of cement, the discharge being at one corner. During the steeping, which lasts from two to ten weeks according to the nature of the raw material, the stock is frequently stirred with long-pronged forks so that every part may be equally acted on by the lime. When the skins are considered firm and free from any greasy feel, the milk of lime is run off, and the vats or pits refilled with clean cold water, containing a small proportion of hydrochloric acid, which dissolves the adhering lime. This washing with acidulated water being completed, the stock is removed to

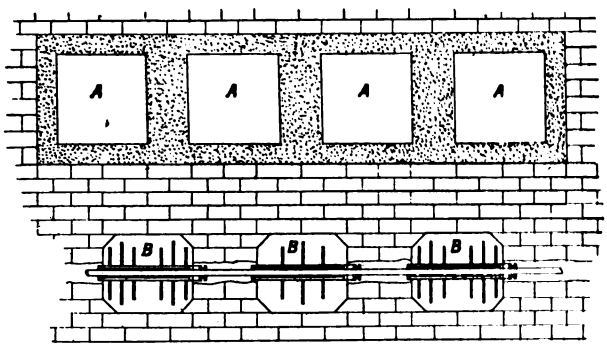


FIG. 19.—Steeping pits and washers. Plan.

a series of washers placed near to the steeping vats or pits and thoroughly washed with clean cold water until the last trace of acid disappears from the wash-water.

The washers are built of wood, or are brick-lined square pits in each of which is fitted a revolving shaft or drum with projecting curved spokes. These on turning revolve backwards, instead of forwards, a movement which enables the washing to be effectively done, while at the same time the skins are not lifted too much out of the water. In fig. 19 is shown a plan of the steeping pits A A A A and the washers B B B. The wet stock on removal from the washers is either hung on racks to drain and dry, or made into bundles and pressed

between the plates of a press to squeeze out the water, and then dried by exposure to the air.

The cleansed and dried stock is now ready for conversion into a glue liquor, and this operation forms the second stage of glue manufacturing.

In the extraction the method adopted varies with the quality of glue to be made. For instance, in the manufacture of the well-known Scotch glue the prepared stock is placed in a loosely woven sack, which is lifted by a crane into a circular kettle heated from the bottom and sides by a steam coil. Water is now added, and gradually brought to ebullition. As the animal substances decrease in bulk, fresh additions are made, the whole being occasionally pressed down by means of poles.

The progress of the operation is readily ascertained by withdrawing a sample of the liquor, and if it shows a firm jelly on cooling, the boiling has been carried to a sufficient extent. After the mouth of the bag has been securely tied up it is slowly raised by appropriate machinery until it comes in contact with, or is partially coiled round, a stout beam immediately above the kettle, which expels the fluid. In this state it is left to drain. Meanwhile the liquor is concentrated to a strength of 32 per cent. dry glue and then run from the kettle to a receiving tank, from whence it is drawn to the coolers for jellying. Having become a firm jelly, the glue is cut out in cubic masses, which are then cut into cakes of the thickness required by a cutting machine.

The drying of Scotch glue is of the same primitive character as the boiling, and can only be carried on for about eight months in the year, when temperate and equable weather exists. Exposed on nets stretched on a wooden framework and built up to form a stack which is covered by a Λ-shaped roof, the cakes, by their exposure, are liable to be injured by the least atmospheric change. For instance, if the weather

becomes too hot the glue may become soft and unshapely, so much so as to run through the meshes of the netting on to the cakes below; or the drying may be so rapid that it is prevented from contracting to its proper size without forming numerous cracks and fissures. On the other hand, a sharp frost will congeal the water in the cakes and thus produce numerous cracks, which deteriorate their value. Again, in foggy weather the moisture condensed on the surface of the glue favours the growth of mould. These dangers have

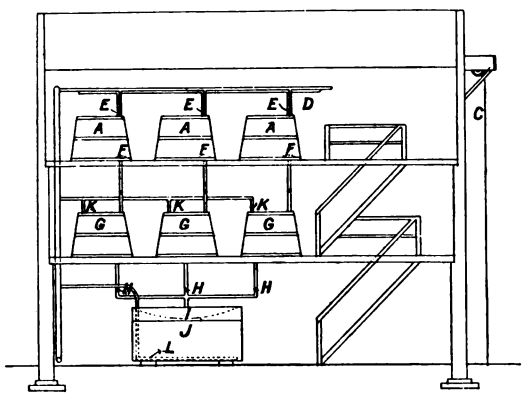


FIG. 20.—Boiling and clarifying house for skins. Section.

always to be guarded against in open-air drying, for they render the process a very precarious one.

The cakes when about three parts dry are removed from the netting, threaded on strings, and hung up to harden in a dry room. Owing to the dull and soiled appearance presented by the dried cakes, they are further dipped in cold water and rubbed with a brush, which renders their surfaces glossy and more attractive. In the manufacture of other brands of hide glue, the modern method of boiling the cleansed and dried stock along with the clarification of the resulting glue liquors is shown in section, fig. 20. The

building (in addition to the basement, fig. 22) carries a first and second floor, part plans of which are seen in fig. 21. On the second floor are placed the six boiling vats A, three

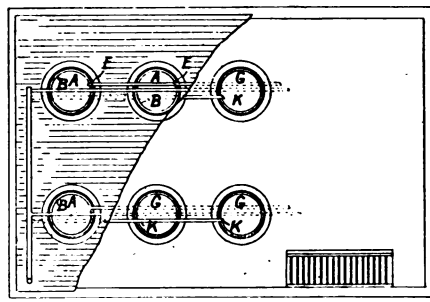


FIG. 21.—Boiling and clarifying house for skins.
Part plan, first and second floors.

being shown in section and plan. They have a depth of 6 feet and a diameter of 5 feet, and are built of 2-inch staves tightly bound with iron hoops. Each vat is provided with

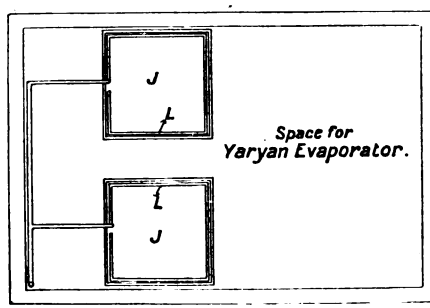


FIG. 22.—Boiling and clarifying house for skins. Ground floor plan.

a false bottom, under which rests the 2-inch steam coil B for heating purposes. The raw material is lifted by the hoist C to the second floor, and conveyed by a bogie to the boiling vats. After charging with the cleansed stock, water is

supplied from the main D, and distributed to each vat by the branch pipe E, the whole being gradually brought to a gentle boil by an injection of steam through the coil B. As the boiling proceeds, the raw material decreases in bulk, owing to its solubility in hot water, and more is added until a sample of the liquor shows it to be of the right strength, which is indicated by the firmness of the jelly produced by the sample on cooling; or the sample may be more accurately gauged by the glue meter, which, on insertion, registers the strength in percentages of dry glue. When the desired density is attained, the liquor from each vat is run through the strainer or sieve F to a corresponding vat below, G, for clarification.

The clarifiers, of which three are shown in section, fig. 20, and three in part plan of first and second floors, fig. 21, are heated by the steam coils K K K, and the liquors are clarified with potash alum in a manner similar to the treatment of bone-glue liquors, and on opening the outlet valves H H H they flow through the filters to the large storage tanks J J on the basement floor, which are heated by the steam coils L L. From the tanks the clarified liquors are pumped to the Yaryan evaporator for concentration.

The residual matter left in the vats after the first and second boiling is boiled a third time to exhaust all the glue, and the resulting solution is, without clarification, jellied for size (containing from one-half to one per cent. of nitrogen, mainly of a non-gelatinous nature); the refuse remaining after the third boiling is used in the mixings of the manure house after drying by exposure to the air or by waste heat.

The concentrated liquors, after bleaching, are jellied in troughs or cast on glass slabs, as previously described, before drying.

In France some manufacturers adopt a closed in place of an open boiling of the skins, the operation being carried

out in a battery of closed vessels working together in a manner similar to a diffusion battery in a beet-sugar manufactory. The advantages claimed for the method are less manipulation, with lower steam consumption, along with a higher strength of liquor and a more exhaustive extraction.

To sterilise, bleach, and lime at the same time by the use of bisulphite of lime in place of milk of lime has been suggested in the treatment of the raw material. No sufficient evidence has been furnished to show that the change, however desirable it may be, would result in a better swelling of the glue pieces, and consequently an improved quality of glue.

Fish Glue.—Isinglass made from the bladders or sounds of fish is the purest form of gelatine, but a strongly-smelling glue which has considerable adhesive power is obtained to a limited extent from the offal. In an undried state fish contains 25 to 30 per cent. organic matter, which yields 2 to 2½ per cent. of nitrogen, and it is from this body that the glue derives its origin.

The offal is carried by conveyors to a series of washing tanks placed overhead, and thoroughly washed with water to remove the blood, etc. From thence it falls by gravitation into the digesters, and is heated with 'live' steam for ten hours. The oil and gelatinous water are drawn off by a pipe fixed to the bottom of each digester, into tanks, the oil skimmed from the surface, and the glue liquors clarified with a small proportion of alum. On filtering, they are concentrated in open vats provided with a steam coil, to a strength of 32 per cent. dry glue, and then bleached with sulphurous acid. The residue left in each digester is dried in a jacketed cylinder, and then mixed with proportions of the double salts of potash and magnesia, to form fish-potash guano.

Fish glue is a light brown viscous liquid with an offensive

odour and an acrid taste. It forms a sticky mucilage when diluted with water, and as met with in commerce already contains about half its weight of water, and such a liquid is, weight for weight, only about equal to a dextrine in viscosity. If the comparison were made on the dried fish glue, of course, it would stand much higher, equalling some of the second-class gum-arabics.

The ash of fish glue is comparatively high, about 4 per cent. on the body dried at 100° C. It is usually white in colour, and contains, besides carbonates of calcium and potassium, some 5 to 10 per cent. of phosphate of calcium. According to Rideal, fish glue on boiling with potash assumes a greenish-yellow colour, and absorbs about 9 per cent. of the caustic. Liquid gums of this class are easily recognised by boiling with Fehling's solution, when they assume a violet colour, and by the tannic acid reaction. The unpleasant odour and taste of fish glue is one of the objections to its use, and the best method to remove these disadvantages is to boil the fish glue dissolved in a little water with 1 per cent. of phosphate of sodium, and adding ·025 per cent. of saccharine.

Dissolving of Glue.—The ordinary way of making a solution of glue is by breaking the cake into pieces of a convenient size and dissolving them with a little water in a vessel heated by boiling water. An improved method is to break the cake into small pieces, soak in water until soft, drain off the water, and place the swollen pieces, which have absorbed sufficient water to form a solution when melted, into the glue pot, fill up the outer vessel with water, and heat over a fire, or, better still, a Bunsen flame. When thoroughly melted, use at once, for the hotter a glue solution is when applied, the greater will be the breaking strain of the two surfaces glued together. A glue solution when allowed to cool and then re-melted has not the same tenacity as a freshly-prepared solution. Consequently, for ordinary

work, the quantity of glue solution prepared should not be more than is required for immediate use.

To facilitate the dissolving of glue it has been suggested to cast the glue in strips, or pencil lengths, and dry them in this form. By this method it is claimed that the strips will not cake when heated with water in the glue-pot, and will not bunch together so as to prevent liquefaction, but, due to their form, provide interstices between the strips, through which the heat travels.

Adhesiveness of Glue.—The value of glue depends on its adhesive power or strength. Under favourable circumstances, this is equal to a force of at least 715 lbs. per square inch. In one experiment, a force of 1260 lbs., applied gradually, was found necessary to separate two cylinders of dry ash wood, the ends of which presented a surface equal to 1·76 square inches, and which were glued together, end to end, and allowed twenty-four hours to set. Even this weight was sustained for two to three minutes before the joint gave way, and it was found, on examining the separated surfaces, that the glue was very thin and had not entirely covered the surface.

The cohesive strength of the glue appears, therefore, in this experiment to have been rather more than 715 lbs. per square inch, while the cohesive strength of the wood thus united, in a lateral direction, was found to be only 562 lbs., thus showing that if the joint had been between the sides, instead of the ends of the pieces of wood, the wood would have given way before the glue. In this case, however, the glue was newly made, and the season very dry, while in some former experiments made in the winter season with glue which had been frequently made with occasional additions of glue and water, the cohesive power indicated was only 350 to 500 lbs. per square inch. On the other hand, Mr Bovan found, in some experiments, that the cohesive force of solid glue was equal to 4000 lbs. per square inch, from which it may be

inferred that the application of glue as a cement is capable of much improvement, and of showing a more satisfactory result than the above-mentioned experiment.

Glue that has been made a long time and kept in store is found to possess greater tenacity than glue newly manufactured, and for the use of the joiner, pale-coloured glue is preferred to that of a dark tint, as it produces neater and less apparent joints. With the cabinetmaker the colour of glue is of less importance, owing to the less frequent employment of the glue in joints exposed to the eye.

The more a body of glue penetrates the pores of the wood, the more efficient is the joint. Glues that take the longest time to dry are preferable to those that dry quickly, the slow-drying glue always making the strongest joint, other things being equal. Do not use thick glue for joints or veneering. In all cases work it well into the wood, as painters do with paint. In using glue, cover both surfaces of the work, except in case of veneering. Never glue hot wood, as it will absorb all the water in the glue too suddenly and leave only a very little residue.

In determining the adhesive power of glue Weedenbusch has devised a very ingenious method. He first prepares a series of plaster prisms by mixing water and gypsum together in the proportion of 1 to 5. These prisms are 4 inches long, with a cross-section of $\frac{1}{6}$ inch, and each weighs 26 grains. The glue solutions were made from 1 part of glue dissolved in 25 parts of warm water, and the plaster prisms were soaked in them for five minutes. Each prism is then placed on a horizontal iron ring, in such a position as to form its diameter, and from its centre is suspended a pan in which weights are placed until the prism breaks. The strain it can withstand is proportional to the adhesive power of the glue.

CHAPTER V.—GELATINE.

GELATINE, which is a pure form of glue, is largely used for culinary purposes, and consequently in its preparation the raw materials require to be selected with great attention to purity, and the manufacture conducted with the most scrupulous care and cleanliness.

Gelatine is produced from white bones or hide pieces, that derivable from the former being mainly used in the stock for soups, etc., and as prepared gelatine, calves' foot jelly, and patent isinglass.

Bone Gelatine. — The preparation of bone gelatine depends on the separation of the organic from the mineral matter by an acid which dissolves the latter, leaving the ossein in the form of the original bone. The carefully picked and crushed bones may be degreased by a solvent, cleansed, and then subjected to the acid treatment; or, as carried out in some works, the fat is recovered in the after-process of boiling the ossein. In either case the crushed bones are conveyed to a series of vats 10 feet square by 3 feet deep, each of which is three parts filled and then covered with water containing 10 per cent. of hydrochloric acid. Phosphates of lime and magnesia and carbonate of lime mainly comprise the mineral constituents of the bone, and these salts are dissolved out by the action of the acid, leaving the gelatine-forming ossein intact. The steeping usually occupies about four days, the

acidulated water being renewed once during this period. The bones now become soft, leathery, and semi-transparent, and in this condition are sufficiently prepared for washing to remove the acid. This is carried out by filling up each vat with fresh water, allowing it to soak through the bones for six or seven hours, and then draining. The washing is repeated until the wash-water shows no appreciable precipitate on the addition of a few drops of nitrate of silver solution. A slight turbidity may be due to the presence of combined chlorine in the fresh water.

When sufficiently washed, the soft bones are thoroughly bleached by immersion in a 1 per cent. solution of sulphurous acid for three hours, and then conveyed to the vats A, fig. 20, to undergo digestion. The dissolving process is effected in the manner described under skin glue, care, however, being taken that the water covering the soft bones should never exceed a temperature of 85° C. when heated by the steam coils. Above this heat gelatinous solutions are very sensitive as regards colour.

During the digestion, the fat—if the raw bones have not undergone a degreasing process—rises to the surface and is carefully skimmed off from time to time, the skimmings being subsequently washed with hot water, before filling into casks.

A second digestion is necessary to practically exhaust the gelatinous matter, and the first and second runnings from the vats, having a density corresponding to 20 and 12 per cent. dry glue respectively, as indicated by the glue meter, then flow to the clarifiers and are treated with a small quantity of potash alum; from thence the liquors pass through the filters for concentration in the Yaryan evaporator to a jellying strength of 32 per cent. dry glue.

To obtain the colour necessary for a high-grade gelatine, the concentrated liquors undergo a further bleaching in the

tanks E E, fig. 12, and are then run on to the glass slabs to a depth of half an inch for cake and quarter of an inch for leaf gelatine.

As a commercial product leaf gelatine is coloured with dye-stuffs to suit certain trade requirements. Carmine is a colour often employed for this purpose, and aniline colours are also used in the proportion of 1 ounce of colouring matter dissolved in a small quantity of glycerine to every 16 lbs. of liquid gelatine, the solution being strained through linen cloth and then mixed with the concentrated liquors before jellying. In the production of coloured leaf gelatine the liquors are not bleached after concentration. The method of manufacturing gelatine varies; for instance, some French makers substitute phosphoric for hydrochloric acid in dissolving the mineral matter of the bone. For this purpose the carefully picked bones are dried at a temperature not exceeding 100° C. and then pulverised to a coarse powder in a mill. The powdered bones are then introduced into a circular vat provided with a stirrer, and the phosphoric acid, of 12° Tw. strength in the proportion of 1 cubic foot by measure to each 10 lbs. of raw material, is well stirred in the mass. The acid decomposes the carbonate of lime with evolution of carbonic acid, and converts the insoluble phosphates of lime and magnesia into soluble acid phosphates. The stirring is continued until the carbonic acid is wholly driven off; and on allowing the mixture to stand for a time, the crude gelatine falls as a sediment to the bottom. After the supernatant liquor has been syphoned off and precipitated with sulphuric acid to liberate the phosphoric acid for use again as a dissolving agent, the sediment is well washed with cold water and then treated with hot water of a temperature not exceeding 85° C., which dissolves the crude gelatine; the liquor is afterwards clarified, bleached, and concentrated in the usual way.

'Osseine' is a French preparation from bones, and is brought into the market in a dry and concentrated state for the manufacture of gelatine. In using it the product is soaked in water for forty-eight hours, the water being renewed every twelve hours. When it is thoroughly swollen, the 'osseine' is well washed with water until the washings are absolutely clear, and yields a gelatine quite clear and without any smell. The washed product is next bleached for one hour in a bath of sulphurous acid of 1° Tw. strength, and then finally dissolved at a temperature of 85° C. in a wooden vat fitted with a copper steam coil and provided with a double wooden bottom to distribute the heat. The gelatinous liquor is concentrated and jellied without clarification.

Animal charcoal is a powerful decolorising agent, and its use as a filtering medium has met with some success in obtaining a white gelatine from low-grade bone products, and also in improving the colour of the gelatine obtained as a secondary product in the manufacture of neat's-foot oil.

Skin Gelatine.—The preparation of gelatine from the parings and cuttings of hides varies but little from the process as described in the manufacture of skin glue. In some factories, instead of using lime only in steeping the hide pieces, a mixture of caustic soda and lime made into a milk with water is sprayed over the mass in the pits. The use of caustic soda facilitates the saponification of any fat present and the dissolving of the fleshy matter.

Before the digestion, which is effected at a temperature not exceeding 85° C., the hide pieces, on removal from the lime pits, are washed free of any alkalinity, and are then bleached by sulphurous acid to destroy any injurious colouring matter. To completely exhaust the gelatinous matter during digestion, three 'boilings' are generally required, the first and second runnings being treated for gelatine, while the third is simply filtered for size.

A very fine water-white leaf gelatine is produced by cutting the jelly into small pieces, washing well with cold water and re-melting at 80° C., then pouring the liquor on the 'glasses' to the depth required.

Seaweed Gelatine.—A product hardly distinguishable from gelatine, and used for many purposes in the arts similarly to that body, is known as seaweed gelatine, and is produced from a genus of weed to which the name of *Laminaria* is given. When macerated with water, about 33 per cent. of the weight of the air-dried weed is removed. The residue, when digested with carbonate of sodium, is partly dissolved, forming a soluble compound of sodium alginate. On filtering, the filtrate is mixed with hydrochloric acid, which liberates the alginic acid. The acid is washed, bleached, and re-dissolved in alkali, and by concentration in a vacuum pan and then running on glass plates or porcelain slabs, the sodium alginate is obtained in the form of transparent flexible sheets like gelatine and having the same colour, but they are not gelatinous. These sheets can be rendered insoluble without altering their appearance by immersion in dilute hydrochloric acid; they can also be readily coloured like leaf gelatine.

In America a gelatine is made from seaweed, called by the native name of Tengusa. The weed is carefully dried and afterwards boiled so as to form a glue-like decoction, which is strained off and put into square boxes. When cool it forms a thick jelly, which can be easily divided into squares a foot in length. The manner in which the surplus water is removed is very ingenious. The jelly prisms are exposed in the open air during a cold night and allowed to freeze. During the day the sun melts the ice to water, which runs off, leaving behind what might be termed a skeleton of white horny substance, which is extremely light, and easily dissolved in hot water; when cool, it again forms

a stiff jelly. This article can be applied to many purposes—for culinary purposes, for making bonbons and jellies, for clarifying liquids, as a substitute for isinglass, for making moulds used by the plaster-of-Paris workers, for hardening the same material—in short, as a substitute for all kinds of gelatines, over which it has the advantage of producing a firmer jelly.

Comparison of French and British Gelatines.—The ash and water absorptive-power are indicative of the value of a gelatine, and in the following table a comparison is made of gelatines of French and British manufacture.

	Brand.	Ash.	Water absorption by 28·34 grams of Substance taken.
French	Coignet's gold label,	1 per cent.	340·08 grams.
	Coignet's special,	1 ,, ,,	340·08 ,,
	Ordinary French,	2 ,, ,,	292·81 ,,
British	Nelson's No. 1,	2 ,, ,,	283·40 ,,
	Swinburne's No. 2, Patent isinglass,	1 ,, ,,	311·74 ,,
	Cox's packet gelatine,	2 ,, ,,	279·62 ,,

The Behaviour of Gelatine with certain Salts.—Gelatine is unaffected when in contact with solutions of lead, tin, nickel, cobalt, manganese, aluminium, magnesium, and other metallic salts. With a solution of chloride of barium it is completely dissolved. It is also, although to a smaller degree, soluble in chloride of strontium. Other chlorides, such as those of potassium, sodium, and calcium, do not act in the same way, nor do their iodides or bromides. With a solution containing 15 per cent. chloride of barium, the solubility is so great that sufficient gelatine may be dissolved to render the solution syrupy in consistence. The liquid keeps well, and does not decompose under the action of air.

Allowed to evaporate spontaneously, it leaves behind a solid white substance which, when examined under the microscope, shows itself to be composed of an amorphous mass of filaments mixed with fine crystals of chloride of barium, but it does not appear that any combination has taken place. This solid substance dissolves in water completely. When exposed to light, gelatine is rendered insoluble in the presence of bichromate of potassium. Gelatine is precipitated from its solution by chloride of iron both in the light and in the dark.

CHAPTER VI.—SIZE AND ISINGLASS.

Size.—As a cheap and easily workable agglutinant, size finds a ready use with calico-printers, painters, decorators, and in the carpet, straw-hat box, wallpaper and other trades. Size is undried glue, and exists as a tremulous jelly, possessing all the adhesive properties of the latter, but in a much less concentrated form.

In a sense, size is a bye-product in the manufacture of glue and gelatine, for the third liquors in the exhaustion of the raw material only are used for this purpose, and these, if converted into either of the above agglutinants, would yield an inferior product; consequently it pays the manufacturer better to gelatinise it and to sell it in this form without drying. In small works exclusively making bone size the manufacturer with no benzene or glue plant at his disposal simply washes the rough bones in a revolving drum, and after crushing in a mill, feeds the broken pieces into an elevator, which lifts and discharges them into one or more digesters heated by 'live' steam. When the bones are sufficiently acted on, the steam is turned off, and the grease and gelatinous liquor are blown through the outlet pipe to an overhead tank. After separating the fat, which is subsequently well washed with hot water to remove the impurities, the gelatinous liquor is filtered to separate any suspended matter, and then evaporated in a wooden vat fitted with a steam coil to the density required.

During the evaporation a moderate charge of sulphurous acid solution is sometimes added to improve the colour. Size is brought into the market as (1) common size; (2) medium size; (3) best size. The first contains 25 per cent. glue and 75 per cent. water; the second, 30 per cent. glue and 70 per cent. water; and the third, 38 per cent. glue and 62 per cent. water. For exportation a stronger size is made in three grades, No. 1 containing 40·5 per cent. glue, No. 2 44·5 per cent., and No. 3 49 per cent., the liquors being evaporated to these densities before jellying.

Glue or gelatine in a dried state is a very stable body, but in the form of a jelly it soon ferments, becoming sour and mouldy, unless some preservative agent is used to prevent decomposition. For this purpose sulphate of zinc is principally used; boracic acid, and also a preparation known by the name of 'Salinfer,' have been used with good effect. These preservatives are added to the liquors before running into the casks to set.

In sorting the cakes of glue before packing, a number are always found unsuitable, owing to their having become twisted during the shrinkage in drying, or not equal to the standard as regards colour. These defects, while not lowering to any appreciable extent the value of the cakes as an agglutinant, yet affect their selling power. They now find a ready sale in a powdered condition as 'Concentrated Size' or 'Glue Powder,' the cakes being ground, sifted, and graded by suitable machinery.

Isinglass.—The purest form of commercial gelatine is isinglass. This valuable product is obtained from the swimming bladder or sound of various species of fish, of which the sturgeon yields the finest quality. Isinglass is brought into commerce under the name of pipe, lump, honeycomb, purse, leaf, and other designations, and these different kinds are due to the method of preparing the

bladder. For instance, pipe, purse, and lump isinglass consists of the sound desiccated, but unopened; while in the leaf and honeycomb kinds the bladder is cut open and then dried unfolded. When the cut bladder is folded and dried, the product is known as book isinglass, while in the ribbon isinglass it is rolled out. From Russia is obtained the finest quality of isinglass in the form of leaf, book, and long and short staple, the four varieties principally coming from Astrakhan and Taganrog. In preparing Russian isinglass, the swimming bladder is first cleansed of the mucus and blood stains by immersion in hot water, then cut open longitudinally and exposed to the air with the inner delicate silvery membrane upwards. When dried this fine membrane is removed by beating and rubbing, and the swimming bladder is made into the different forms by twisting or folding.

Brazilian isinglass is imported from Para and Maranham in the form of pipe, lump, and honeycomb. Pipe Brazilian isinglass is prepared by drying the swimming bladder unopened. When dry, each bladder is from 10 to 12 inches long and 2 to 2½ inches broad, weighing about 5 ounces. Lump Brazilian isinglass consists of two swimming bladders placed side by side, considerably separated at one end, but communicating with each other at the other extremity. An average-sized lump will weigh about 6½ ounces. Honeycomb Brazilian isinglass is the lump variety split open. The latter is sometimes softened and rolled out into thin strips, and is then known as ribbon isinglass. Brazilian, and also the isinglass imported from Hudson's Bay, Penang, India, etc., is the product of different species of fish, and is darker in colour and less soluble than the Russian variety. As received in this country, isinglass is a hard and tough substance, and for many purposes it requires to be cut into fine shreds to facilitate its solution. According to Watson Smith, there seem to be only six

isinglass cutters in England, all being domiciled in London. The crude isinglass is first sorted, soaked in water until it becomes a little pliable, and then trimmed. Sometimes it is just pressed by hand on a board with a rounded surface; at others it is run once between strong rollers to flatten it a little and make the dark and dirty spots accessible to the knife, the top of the roller being used to bend the pieces on.

The cuttings are sold separately as an inferior grade. The next process is that of rolling. Very hard steel rollers, powerfully and accurately adjusted, are used. They are capable of exerting a pressure of 100 tons. Two are employed, the first to bring the isinglass to a uniform thickness, and the smaller one, kept cool by a current of water, to reduce the isinglass to a little more than the thickness of writing paper. It is very curious to see the thick, tough pieces gradually spreading out under the rollers and folded and rolled like puff pastry, till the separate pieces so unite themselves that no joint can be seen, and the mass is reduced, under the coarse rollers, to what looks like semi-transparent millboard. From the finer rollers it comes in a beautifully transparent ribbon, many yards to the pound, 'shot' like watered silk, in parallel lines about an inch broad. It is now hung up to dry in a separate room, the drying being an operation of considerable nicety. When sufficiently dried, it is stored till wanted for cutting, or is sold as ribbon isinglass to those who prefer this form.

The machines for cutting are well and accurately made, and are so adjusted that they slice pieces off a sheet of paper without bending it in the least. For the fine 'cut' isinglass, these machines are run at a great speed, 2000 to 2500 revolutions, making 10,000 to 12,000 cuts in a minute. It takes an hour to cut 5 lbs., so that every pound would contain 100,000 to 125,000 separate fibres, if none of them were broken. Isinglass is used in but few industries. The largest

quantity is used by brewers and wine merchants for clarifying purposes. This property is extraordinary, for gelatine, which is chemically the same thing, does not possess it. One theory is that the tenacious mucilage shaken with the liquid gradually settles to the bottom, entangling all floating particles as it sinks. Another suggestion is that a very delicate fibrous network remains after the isinglass is dissolved, and entangles the particles in the way that the mucilage is supposed to act. Many varieties, generally the lower brands, are used for this purpose. Some brewers use it in the natural state, others prefer it manufactured into a fine or wide strip, which dissolves quicker and suffers no waste. At present Penang is the favourite kind. Russian long staple isinglass is used only by the Worcestershire farmers for clarifying their cyder. In spite of its costliness, Scotch brewers prefer Russian leaf. For clarifying purposes the isinglass is 'cut' or dissolved in acid, sulphurous acid being used as the solvent, owing to its preservative nature. When reduced to the right consistency, a little of the solution is placed in each cask before sending it out for consumption. Sole skins are sometimes used as a substitute for isinglass. They are only to be had in winter, the supply is uncertain, and they have not the strength of the Penang varieties. Next to the brewers' demand comes that of the cook, who uses it for making jellies, thickening syrups, and stiffening jams. Russian takes the highest position, owing to its superior strength and nourishing properties. Isinglass being the purest natural form of gelatine, a very fine article has long been known in the market as 'patent isinglass,' which is a gelatine of high quality. It does not, however, possess the clarifying power of the natural article, but is equally used for culinary and confectionery purposes. Outside the demands of the brewer and cook, isinglass has but a limited use in the arts. In textile works isinglass is used along with

gum to give lustre to ribbons and other silk articles, while as a substitute for glass it answers well for lamp shades. Isinglass is also used in preparing a substitute for Indian ink; for this purpose three parts of isinglass are made into a size by dissolving them in six parts soft water. In another vessel, 1 part of Spanish liquorice is melted in 2 parts of soft water, over a fire, and then saturated with 1 part of ivory black. The two solutions are mixed together and stirred well. This mixture is evaporated to a thick syrup, and this is run into a leaden mould which has been slightly oiled, and allowed to set firm. The product is much of the same nature and applicable to the same purpose as Indian ink. As an agglutinant, isinglass is used in the form of diamond cement by dissolving two parts of it in four parts of spirit of wine, the solution on cooling yielding an opaque, milk-white, hard jelly. It also dissolves in strong acetic acid, forming a powerful cement, much used for repairing glass, pottery, and similar small objects.

The well-known court plaster is made by brushing a solution of isinglass, mingled with a small quantity of tincture of benzoin, over black sarsenet.

Isinglass is not suitable for photographic work, on account of its great solubility and inferior tenacity. The composition of isinglass, so far as required for commercial purposes, is as follows :—

	In parts per 100.		
	Ash.	Water.	Insoluble.
Astrakhan, ...	0·2	16·0	2·8
Fine Russian, ...	1·2	17·0	1·0
Russian pipe, ...	0·8	19·0	3·0
Lump Brazilian, . . .	1·4	14·0	4·6
Honeycomb Brazilian, . .	1·1	12·0	5·2
Royal northern bladder, . .	3·2	15·0	10·8
Siberian purse, ...	·85	14·0	3·9
Cayenne Brazilian, . . .	1·49	12·0	6·2
Indian, ...	·78	8·0	8·6

CHAPTER VII.—EFFLUENTS: MARROW BONES AND BYE-PRODUCTS.

Treatment of Effluents produced in Glue and Gelatine making.—In face of the growing stringency of the public authorities in dealing with trades' effluents, the disposal of the waste and wash waters from the various operations in the factory becomes an important matter. These waters contain a large proportion of suspended and dissolved mineral and organic matter, and their discharge into a water course without treatment of any kind would form a source of pollution, rendering the manufacturer so offending liable to severe penalties under the Rivers Pollution Prevention Act.

Formerly the effluents were treated in a very primitive way by running them into roughly-made ponds, whence, after a partial subsidence of the suspended matter, the still muddy liquors were allowed to percolate through the soil. An improvement on this was the system of filtration through layers of coke and sand, which, while retaining the suspended matter, failed to remove any in a dissolved state.

To meet the high standards of purity enforced by many County Councils, some form of treatment which would remove both the soluble and insoluble impurities became necessary. This is now carried out chemically by a method of precipitation with soda-ash and alumino-ferric, the applica-

tion of these reagents in the treatment of the effluents being shown in figs. 23 and 24, which illustrate the Archbutt-Deeley installation for the purification of waste and wash waters.

The Chemical Trades Journal, in describing this apparatus and its working, says that it consists of a large tank A, which may be constructed of brick, concrete, or iron. The waste water to be treated is admitted at the inlet B. While the tank is filling, the chemicals required for precipitation are weighed out and boiled up with water in the small chemical

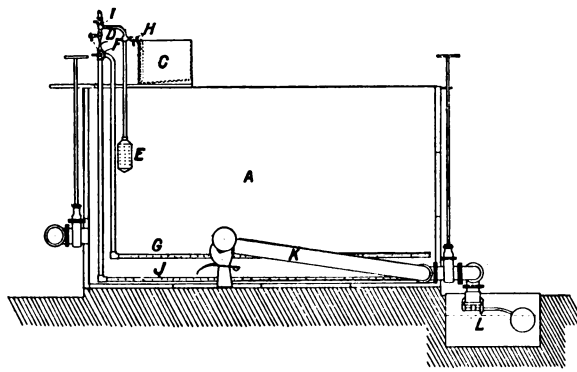


FIG. 23.—Archbutt-Deeley purification plant. Section.

tank C by means of live steam. When the tank is full and the inlet valve has been closed, steam from the boiler is admitted to the blower D, causing a current of water to circulate through the rose E, the threeway tap F, down the vertical pipe, and back into the tank through the perforations in the upper row of horizontal pipes G. On opening the small tap H the prepared chemical solution is slowly drawn into the circulating current and uniformly diffused throughout the body of water in the tank. The tap I is next opened to admit air through the pipe at the top of the blower, and by reversing the threeway tap F this air is forced through the

perforations on the under side of the lower row of pipes J. From these it rises in streams of bubbles, stirring up some of the precipitate from previous operations, which, when diffused throughout the water, carries down the flocculent particles of freshly-formed precipitate. Any residual virtue in the precipitant from the previous batch is also utilised, thus effecting considerable economy in chemicals. Steam is then turned off, and in about thirty minutes to one hour nearly all

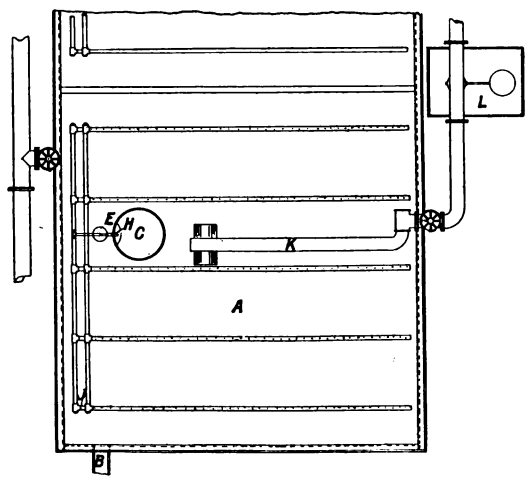


FIG. 24.—Archbutt-Deeley purification plant. Plan.

the precipitant will have settled to the bottom of the tank, and the supernatant water, even to a depth of six feet, will not average more than about one grain of suspended matter per gallon. The clear water is drawn off by the floating discharge pipe K to a receiving tank L, from whence it may be run to a stream or sewer.

The precipitated sludge has a manurial value when in a dried state, due to the nitrogen and phosphate of calcium it contains. To prepare it for use in the manure shed, it is

pumped into a powerful press which removes fully 90 per cent. of the water, the pressed cakes being subsequently dried by waste heat, then pulverised by passing through a disintegrator, and used in the compounding of low-grade manures.

Marrow Bones.

On the raw bones entering the works, the leg and thigh bones, known as 'marrows' or 'knuckles,' are separated from the heads, ribs, etc., and undergo a treatment different to that of the latter. In the first instance, the 'marrows' are not treated with a solvent; and secondly, they are only partially degreased and degelatinised in the slow boiling they receive. The object is to remove only a portion of the fatty and gelatinous matters, leaving the bone firm and hard so that it can be turned in a lathe. If the boiling is excessive and prolonged, the bone becomes chalky and soft, and thus useless for conversion into the many articles of everyday life.

Treatment.—In working the 'marrows' the ends are sawn off by a circular saw to open out the core and thus facilitate the removal of the fat in the after-process of boiling. The cut bones are now steeped in cold water containing 1 per cent. of salt for three or four days, to separate the fibrous matter derived from the fine bloodvessels. After washing with water they are conveyed to a large circular vat provided with a steam coil and a double bottom to distribute the heat. The bones are covered with water, which is gradually brought to a simmer and maintained at that for six hours. During the heating all the fat in the core of the bone is removed along with a part of the gelatinous tissue, the former rising to the surface, while the latter is dissolved in the hot water. The fat is skimmed off from time to time, bleached, and then used for the making of high-class toilet

soaps, or, in the unbleached state, the fat oil is expressed, and used in adulterating neat's-foot and other highly-priced oils, while the residual stearine is of value to the candlemaker.

Composition of Extracted Fat. — The following analyses represent the composition of the bleached fat:—

	In parts per 100.		
Water, . . .	·58	·94	·76
Organic matter other than fat, . .	·04	·07	·01
Mineral matter, .	·11	·15	·23
Fat, . . .	99·27	98·84	99·00
	100·00	100·00	100·00

The mineral matter is mainly phosphate of lime.

The water, which has extracted 8 to 9 per cent. of gelatinous matter, is chiefly used for the preparation of high-class size for cardboard boxmaking, and with this object it is run through a filter of coarse woven calico into a receiving tank, the filtration removing the phosphate of lime and other suspended impurities. If further clarification is necessary to remove any soluble organic matter other than glue, it is carried out in the tank in the manner described under 'bone glue,' with a small proportion of alum. On filtering, the liquor is run into a vat heated by a steam coil, half a bucketful of sulphurous acid, 3° Tw. strength, added, and then evaporated to a density of 32 per cent. dry glue as registered by the glue meter. The partially degreased and degelatinised bones are now removed from the boiling vat, and each one is scrubbed with a brush to detach any meaty matter, then placed on a rack and air-dried.

Uses.—The dried bones are used for manufacturing buttons, knife-handles, spoons, paper-knives, and many fancy articles of daily use; the residual trimmings in cutting the rough buttons from the bone slabs are used for gelatine

making; and the dust formed in drilling the eyes is used as a food for poultry and dogs.

Partially Degelatinised Bones and their Conversion into Animal Charcoal, etc.—With a carbonising plant at his disposal the manufacturer is well advised if he only partially degelatinises the degreased bones—that is, extracts only half of the nitrogenous and carbonaceous matter as glue and carbonises the remainder to animal charcoal, using the tar, ammoniacal liquor, and uncondensed gases forming the bye-products; the two former for the production of bone pitch and sulphate of ammonia respectively; and the latter, after purification, for illuminating or motive purposes.

Carbonisation.—Animal charcoal made from partially degelatinised bones is of a deep black colour, and has a metallic ring when struck. As it contains the limit of fixed nitrogenised carbon (10 to 11 per cent.) necessary for a high-grade charcoal, it is fully equal to the product made direct from undegelatinised bones. The carbonisation is effected in a series of retorts, 12 feet long, fixed horizontally in a furnace, and heated from a fire beneath. The retorts are made of cast iron, and five are fixed in each furnace, forming what is known as a 'bench.' At the open end is fixed the frame, which carries the door swung on a hinge. Bolted on to the upper surface of the frame is the up-take pipe leading to the hydraulic main, containing a layer of ammoniacal liquor, into which it dips, and thus effectually closes the retort against any back-rush of gases during drawing and charging. Each retort takes a charge of 5 cwts., which requires twelve to thirteen hours for complete carbonisation.

When ready for withdrawal the door of the retort is slightly loosened by turning a lever, the escaping gases are burnt, and in a few minutes the internal pressure is destroyed, allowing the door to be opened widely with safety.

The red-hot charcoal is rapidly withdrawn by the retort-

man into a canister, covered with a lid, and rolled to the cooling shed of the mill, where the lid is made airtight by a luting of charcoal dust and water, and the canister allowed to cool for twenty-four hours.

Milling.—When cooled, the charcoal is watered, and then conveyed to the mill, undergoing first a cutting into small pieces by two revolving toothed wheels, and then a riddling action in revolving cylinders covered with a No. 7 wire cloth. The fine and coarse particles passing from the cylinders are coarsely ground and then passed to a second set of cylinders or riddles covered with a 60-mesh wire cloth, the dust coming through the cloth being bagged and used in the manufacture of superphosphates and ivory black. The clean charcoal is then conveyed to a third set of riddles covered with wire cloth to suit the grade of charcoal required, and finally bagged as grade 14/60, 12/20, 20/30, or any other grade required by the buyer.

The grading of these charcoals is seen as follows:—

Grade 14/60.		Grade 12/20.		Grade 20/30.	
Size 14	3·98	Size 12	2·88	Size 20	2·14
,, 16	4·28	,, 20	87·15	,, 30	71·85
,, 18	10·66	,, 30	8·39	,, 40	15·63
,, 20	26·89	,, 40	·55	,, 50	6·17
,, 30	30·82	,, 50	·46	,, 60	3·14
,, 40	10·39	,, 60	·29	Dust	1·07
,, 50	7·24	Dust	·21		100·00
,, 60	3·42		99·93		
Dust	2·32				
	100·00				

In a high-grade charcoal the amount passing through a riddle, size 40, should not exceed 2 per cent.

Tarry and Ammoniacal Liquors.—The tarry and ammoniacal vapours leaving the hydraulic main are passed

to the condensers, consisting of a series of pipes vertically placed, through which the hot gases ascend and descend, until their temperature is reduced to 85° F., this reduction of temperature condensing the vapour, which, as a liquid, runs into the separating tank; from the difference in gravity the tarry matter rises to the surface and is floated off to the tar well. The ammoniacal liquor is pumped from the separating tank to the ammonia still, and the ammonia distilled over by steam heat into the 'sulphate box,' neutralised with sulphuric acid to saturation point, when the sulphate of ammonia separates out in fine particles or crystals falling to the bottom of the box, and at intervals are 'fished out' by a ladle, drained, and dried by air exposure. From the well the tar is pumped to a still heated by a fire underneath, and on distillation the volatile products, after condensation, yield an oily liquid to which the term of 'bone oil' is given, while the residue, on running from the still, solidifies as bone pitch, and is used mainly in the manufacture of black varnishes, Brunswick black, ivory black, etc. The uncondensed gases from the condensers are purified by passing over lime, stored in a gas-holder, and used for motive or illuminating purposes.

Yield and Composition.—The yield of animal charcoal amounts to 55 or 60 per cent. of the bones retorted, and the following analyses, made by the author, represent its composition:—

	In parts per 100.	
Moisture,	7·41	6·33
Carbon (nitrogenised),	10·49	11·16
Phosphate of calcium,	74·17	72·64
Carbonate „ „	5·96	7·97
Sulphate „ „	1·22	·89
Oxide of iron,	0·06	·14
Sand,	·69	·87
	100·00	100·00

CHAPTER VIII.—LIQUID AND OTHER GLUES, CEMENTS, Etc.

FOR many purposes an agglutinant which permanently retains its liquidity is found more suitable than the ordinary cake of glue which requires to be melted in water before it is available for use. To supply this want we have the numerous soluble and liquid glues, formed by adding to the glue, when in solution, some ingredient which, while it destroys the gelatinising property, does not impair its adhesiveness. The following collection of recipes is large; only those have been selected which were believed to be trustworthy and valuable. They were taken from periodical literature and other sources.

Liquid Glues.

(1) Possessing great resisting power.

Clear gelatine, . . .	100 parts
Glue, ...	100 „
Alcohol, ...	25 „
Alum, ...	2 „

Mix the whole together, and then add 200 parts of 20 per cent. acetic acid, and heat on a water-bath for six hours.

(2) *Improved liquid glue.*—Dissolve 3 parts glue in 12 to 15 parts saccharate of lime. On warming, the glue dissolves rapidly and remains liquid when cold, without losing its

strength. Any desirable consistency may be obtained by varying the amount of the saccharate.

(3) Dissolve 2 parts fine glue in 4 parts water heated over a water-bath. When dissolved, add 2 parts glacial acetic acid.

(4) Dissolve 16 parts of best white glue in 32 parts water by heat; when dissolved, add 4 parts dry white lead, and stir well. Add the alcohol, and continue the heat for a few minutes; lastly, pour into bottles while it is still hot.

(5) A liquid glue of great strength and useful for a variety of purposes is made by dissolving 30 parts of good glue in a solution prepared by melting in 20 parts dilute phosphoric acid 4 parts carbonate of ammonium. The glue is stirred into the solution, heated to 70° C. until dissolved, and the mixture allowed to cool.

(6) For printing purposes, a liquid glue is prepared by dissolving 28 parts of a good quality of glue in 56 parts of hot water. On complete solution 28 parts of fused chloride of magnesium are added, and stirred well until melted. As a preservative, 1 part of boracic acid is added, and the mixture is allowed to cool for twenty-four hours, when it is ready for use.

(7) Fifty parts of glue are dissolved in 125 parts of hot water. When melted, add 30 parts chloral hydrate, stir well, and allow to cool for forty-eight hours. The solution, which remains perfectly fluid, forms an excellent adhesive for mounting photographs.

(8) Dissolve 3 parts of good glue in 5 parts nitric ether; the ether will only dissolve a certain amount of glue, therefore the solution cannot be made very thick; on complete solution it will be about the consistency of syrup, and is much more tenacious than glue made with hot water. It is improved by adding a few pieces of indiarubber, cut small, and the solution is then allowed to stand a few days, stirring frequently.

(9) A very strong liquid glue is prepared by dissolving 4½ parts of glue in 15 parts warm water, allowing to stand, and then adding ¾ part hydrochloric acid and ⅛ part sulphate of zinc. Heat at 90° C. for ten to twelve hours. It remains liquid after cooling. Used for wood, crockery, and glass.

(10) *Russian liquid glue.*—Soften 50 parts best Russian glue in 50 parts warm water, add slowly 3 parts nitric acid and 3 parts sulphate of lead. Stir well, cool, and bottle.

(11) Brand makes an animal glue by dissolving 60 parts of borax in 100 parts of water, adding to the solution when boiling 4 parts of 90 per cent. calcined potash, and stirring intimately the mixture in 1000 parts of glue liquor of 12° B. strength.

Moisture-proof Glues.

(1) Dissolve 16 parts of good glue in 24 parts methylated spirit, or in the same proportion of skim milk, then add 4 parts of powdered lime, and stir well.

(2) Mix 20 parts of quicklime with 4 parts of linseed oil. Thoroughly stir the mixture, then heat until quite thick, and spread on plates. It will set in a hard mass, and can be melted over a fire like ordinary glue.

(3) Soak 10 parts of glue in the same quantity of water, and remove it before it has lost its primitive form. Then dissolve the swollen glue in 8 parts linseed oil over a slow fire until it forms a jelly. This glue may be used for joining many materials. In addition to strength and hardness, it resists the action of water.

(4) Dissolve 12 parts of glue in an equal weight of hot water, then add 3 parts of yellow resin and continue the heat until melted; finally, add 4 parts of turpentine, and mix thoroughly together on a water-bath.

(5) Dissolve in 16 parts strong methylated spirit 1 part each of sandarac and mastic; next add 1 part turpentine.

This solution is then added to a hot thick solution of glue, prepared by dissolving 12 parts of glue in 16 parts of water by steam heat. The mixture is now filtered, while hot, through cloth or a sieve.

(6) One hundred parts of a thick solution of glue, prepared by dissolving glue in an equal weight of hot water, is mixed with 50 parts linseed oil varnish and 10 parts litharge. Heat for ten minutes, and use while hot.

(7) Dissolve 10 parts of glue in 15 parts of hot water, and add bichromate of potassium in the proportion of $\frac{1}{50}$ of the glue taken. There is no better glue for wood in contact with water than bichromated glue. Allow it to harden thoroughly.

(8) Soak 10 parts of glue in water until it is soft; then dissolve it in the smallest possible quantity of proof spirit by the aid of a gentle heat. In 10 parts of this mixture dissolve 1 part of gum ammoniacum, and, while still warm, add 1 part of mastic dissolved in 3 parts rectified spirit; stir well. It is essentially a solution of glue in mastic varnish.

(9) Glue may be rendered insoluble and thus waterproof, by means of tannic acid dissolved in a small quantity of hot water.

(10) The so-called marine glues found in commerce contain no glue; they are mixtures of benzene or naphtha with shellac, indiarubber, or asphaltum. Jeffrey's marine glue is prepared by dissolving 1 part of indiarubber in 4 parts of crude benzene, and mixing with the solution 2 parts shellac, by heat. The waterproof character of this preparation, its slight elastic flexibility, the ease with which it is applied, when warm, and the promptness with which it sets on cooling, makes it a most useful substance in many applications to house construction and furniture, as well as on board ship, where it was originally intended to be chiefly

employed. Another preparation is made by dissolving 1 part caoutchouc and 2 parts asphaltum in 4 parts naphtha.

White or Russian glue.—White glue is prepared by forming a concentrated solution of glue (5 parts glue to 8 parts water), and, while hot, adding 1 part of white oxide of zinc and 1 part oxalic acid to every 20 parts of the glue solution. Allow mixture to form a jelly, and then dry in the form of cakes.

Tungstic glue.—Tungstic glue has been suggested as a substitute for hard indiarubber, as it can be used for all the purposes to which the latter is applied. It is prepared by making a concentrated solution of glue (5 parts glue and 8 parts water), and adding to this a mixture of tungstate of sodium and hydrochloric acid in the proportion of 2 per cent. of the dry glue taken. A compound of tungstic acid and glue is precipitated, which, at a temperature of 60° C., is sufficiently elastic to be rolled out into very thin sheets.

Chrome glue.—To every 100 parts of a concentrated solution of glue (5 parts glue and 8 parts water), while hot, add 5 parts of dehydrated bichromate of potassium. When dissolved, allow the solutions to set to a jelly; cut into cakes, and dry.

Portable glue.—A very convenient form of glue is known as portable or mouth glue. It is prepared by adding 1 part of sugar to every 4 parts of fine pale glue dissolved, and continuing the heat until the sugar is melted. It is then poured on a slab or plate, and, when cold, cut into squares. The glue is easily softened by the tongue, and is, for many purposes, very handy.

Frozen glue.—A form of glue preferred by many users in America is prepared as follows:—The glue, while in the form of a jelly, is sliced and placed on nets, and allowed to freeze by natural cold. The process can only be conducted in cold weather. The product is porous and much more bulky

than ordinary glue, but it is a better article, and dissolves more easily.

Elastic glue.—An elastic and flexible glue is prepared by dissolving 10 parts of fine pale glue in 15 parts hot water, and then adding 7 parts of glycerine. Heat until the water is driven off; pour on to a marble or glass slab to cool, and cut into blocks about 12 inches square. Elastic glue is of value in the bookbinding trade, for in its use bookbinders get rid of that cracking noise so often heard when opening new books in which ordinary glue has been used in the binding.

Cements.—For binding or cementing purposes, many preparations in which glue or gelatine forms the leading ingredient are used.

The following are the cements chiefly used:—

Glue for repairing broken glass.—Dissolve fine glue in acetic acid to form a thick syrup. Another preparation is made by dissolving equal parts of isinglass and glue in hot water, and straining through coarse linen. Then add a little alcohol, and evaporate by steam heat to such a consistency that, when cold, it will be dry and hard.

Glue for ivory and bone.—Equal parts of isinglass and glue are dissolved in hot water to a concentrated solution, and then 5 per cent. of zinc white is added to bring the whole to the consistency of molasses.

To glue labels to iron.—Make a paste of rye, flour, and glue, formed by adding these ingredients to hot water, and stirring well until the glue has dissolved. To every 16 parts of the paste add 1 part linseed oil varnish and 1 part of turpentine.

To glue leather to iron.—Paint the surface of the iron with a lead pigment, say white lead and lampblack ground up in oil. When dry, cover with the following cement:—Take the best glue, soak it in cold water till soft, dissolve it in acetic acid with a moderate heat, and then add turpentine in the proportion of $\frac{1}{8}$ of the bulk, and thoroughly mix. By means

of a further addition of acetic acid it is brought to a consistency to enable the solution to be spread with a brush. It is applied while hot, and in the application the leather is drawn on quickly and pressed tightly to its place.

Glue for leather goods.—This glue, though complex in composition, gives good results. Eight parts of rye spirit are diluted with 8 parts of water, and the mixture is made into a paste with 2 parts of powdered starch. One part of glue is dissolved in the same amount of hot water; to the glue solution 1 part of turpentine is added, and the solution is thoroughly incorporated with the paste.

To glue leather to metals.—One part crushed nutgalls is digested for six hours with 8 parts of distilled water, and strained. Glue is macerated in its own weight of water for twenty-four hours, and then dissolved by heat. The warm infusion of nutgalls is spread on the leather, and the glue on the roughened surface of the warm metal. The moist leather is then pressed upon it, and dried.

Glue for tablets.—Soak 25 parts of best glue in the same proportion of water for an hour, and then heat until dissolved. To the hot solution add glycerine to the amount of 25 per cent. of the glue dissolved. If too thick, add a little water. The solution may be coloured with aniline colours if required.

Cements for mounting Photographs.—(1) Soak 1 part of gelatine in cold water for an hour; take out, and drain off all the water which will go. Then dissolve in 10 parts alcohol, and add to the solution 1 part of glycerine. The cement will keep for an indefinite time, and has only to be heated when wanted for use. (2) Dissolve 4 parts of gelatine in 16 parts of hot water. When solution is completed, stir in 1 part of glycerine. Allow to partly cool, and then add 14 parts of alcohol. Mix intimately. (3) Make a solution of 1 part of gelatine in 45 parts of

hot water, and then add 10 parts of arrowroot which has been previously mixed with 5 parts of cold water. Boil for five minutes and then add 10 parts of 95 per cent. alcohol, together with a few drops of carbolic acid. Stir well until thoroughly incorporated.

Jeweller's cement.—A cement known as 'Armenian' cement is prepared by soaking 8 parts of gelatine in 64 parts of cold water for twenty-four hours. Then dissolve on the water-bath and evaporate down to half the bulk, and add to the concentrated liquor 32 parts of rectified spirit of wine, straining the whole through muslin. Into this mixture thoroughly incorporate 4 parts of mastic and 2 parts of gum ammoniac dissolved in 32 parts of rectified spirit of wine.

Bottle tops.—A cement is made by dissolving 5 parts of gelatine in 5 parts of water, and mixing the solution with 1 part of glycerine.

Leather.—A cement for leather is prepared by dissolving in the cold 8 parts of indiarubber and 4 parts of gutta-percha in 32 parts of bisulphide of carbon, and then incorporating in the mixture a solution of 2 parts of gelatine dissolved in 2 parts of hot water.

For attaching cloth strips to iron.—A powerful cement is prepared by soaking 100 parts of Cologne glue in cold water for twelve hours, and then pouring off the water. Place the softened glue in a clean copper or enamel vessel heated by steam. During the dissolving, the mass is stirred well with a wooden spatula. If the glue is too thick, it is thinned with spirit of wine, but not with water. As soon as the glue solution has reached the boiling point, 10 parts of boiled linseed oil are added with constant stirring. When completely incorporated, add 10 parts of powdered colophony, shaking it into mass, and stirring well. In order to increase the binding qualities of the cement it is well to add 10 parts

of isinglass, previously cut into narrow strips and dissolved in 20 parts of spirit of wine, this solution being added to the boiling glue liquor. The cement is now ready for use. In the application the iron is warmed and the cement applied to only so much of the surface as one is able to cover promptly with cloth strips. The latter are not pressed down with hand, but with a stiff brush.

Universal cement.—This cement is prepared by dissolving in a flask placed on a water-bath 16 parts of sugar in 48 parts of water, and adding to the thin syrup 4 parts of slaked lime. Keep the mixture at a temperature of 70–75° C. for forty-eight hours, shaking frequently; then cool and decant. Dilute 13 parts of this liquor with 13 parts of water, and in the diluted mixture steep 32 parts of fine gelatine for three hours before heating, to effect solution. Finally, add 3 parts of glacial acetic acid and 15 drops of carbolic acid. Stir well.

Glue for belts.—To prepare a glue for belts, soak 50 parts gelatine in an equal weight of water for twelve hours. Pour off the water and melt the soaked glue on a water-bath. To the hot solution add 5 parts of glycerine, 10 parts of turpentine, and 5 parts of boiled linseed oil. Stir well, and apply while hot.

Glue paste for library use.—(1) Mix 6 parts of rice starch in 48 parts of water, and then add 2 parts of fine glue previously soaked for twelve hours in 5 parts of water. Heat over the water-bath until the glue is dissolved. Cool, and keep in well-stoppered bottles. (2) Mix 12 parts of best Bermuda arrowroot in 3 parts of water, until a thick cream is formed, then thin with 10 parts of water, and add 2 parts of gelatine, previously soaked in 5 parts of water. Boil for five minutes, then set aside to partly cool, and add 2 parts of methylated spirit and 6 drops of carbolic acid. Stir well. Be very particular to add the spirit in a gentle stream.

The paste is kept in well-stoppered bottles, and is applied with a brush.

Glue for paper bags.—This adhesive is prepared by soaking 100 parts of glue in water for twelve hours. Drain off the superfluous water and throw the glue on muslin, and manipulate so as to get rid of as much moisture as possible, then melt on a water-bath. Now add 25 parts of glycerine and 5 parts of syrupy glucose, and stir well in. Finally, dissolve 1 part of tannin in the smallest quantity of water possible, and intimately mix the tannin solution in the glue liquor. The mixture must be used while hot.

Chromium glue for wood, paper, and cloth.—To prepare the glue: (*a*) soak 16 parts of white fish glue in 20 parts of water for twelve hours; (*b*) soak 8 parts of gelatine for six hours in 12 parts of water; (*c*) dissolve 3 parts of bichromate of potassium in 6 parts of boiling water. Dissolve (*a*) and (*b*) over the water-bath, and mix the two solutions together; finally stir in (*c*). This glue is exceedingly strong, and if the article glued be exposed to strong sunlight for an hour, the glue becomes perfectly waterproof. Of course it is understood that the exposure to sunlight is to be made after the glue is thoroughly dry. The one objectionable feature to this glue is its colour, which is yellow brown. By substituting chrome alum in place of the bichromate, an olive colour is obtained.

To glue in brass ornaments.—The falling-out of ornaments embedded in wood, where a visible screw is not desirable, is frequently very troublesome, and a renewed gluing-in rarely obviates the evil, if it is omitted to dip the metal pieces previously in weak nitric acid for half a minute.

Such a bath, with subsequent drying, imparts a moderate roughness to the metallic surfaces which makes the glue take on much better. The glue employed must be exceedingly viscous, and never brittle. It is prepared by dissolving 10 parts of glue in 20 parts of hot water, and to the solution is

added a teaspoonful of glycerine and as much of slaked lime, both ingredients being thoroughly mixed in the glue solution. It should be applied hot on the slightly warmed pieces, which should be quickly pressed into the wood. Metal objects inlaid in this manner never drop out from the wood; they can only be torn out by force, on which occasion a thin layer of the wood is torn away.

Label varnish.—The varnished labels of stock vessels often suffer damage in a very short time from the spilling of the contents over them, or the dripping after much pouring. To remedy this inconvenience, a varnish which is unaffected by the baneful influence of ether, benzene, oil, spirit of wine, etc., is made and used in the following manner:—

Having thoroughly cleaned the surface of the vessel, paste the label on, and allow to dry well. Then it should be given a coat of thin collodion to protect the letters from being dissolved out or caused to run; then after a few minutes paint over it a coat of gelatine, prepared by dissolving 5 parts of gelatine in 25 parts of hot water, being careful to cover in all the edges. Just before it solidifies, it should be gone over with a tuft of cotton dipped in a 40 per cent. formalin solution. It will then soon dry, and become as glossy as varnish.

CHAPTER IX.—USES OF GLUE AND GELATINE.

It has been said that a nation's prosperity may be measured by its consumption of sulphuric acid. With truth it may also be remarked that the demand for glue and gelatine is an evidence of the material progress of a country, for few industries exist in which one or the other of these products does not find a use.

One of the most common services to which glue is put is in the manufacture of matches, this agglutinant, mixed with chlorate of potash and other chemicals, forming the head or striking part of every match made. In the great textile trades a high-grade glue, perfectly sweet and colourless, is largely used in the dressing and finishing of coloured yarns and threads, the sizing of worsted and woollen warps, and the thickening of colours in the printing of fabrics. Many tons weekly of the same quality of glue are also consumed in the manufacture of straw hats.

As an adhesive, glue is a necessity in every class of woodwork, whether it be the manufacture of toys, the making of household furniture, pianos, organs, billiard tables, veneers, door panels, picture frames, or, in general, joinery and carpentry work. When mixed with whiting, white lead, and sawdust, it forms a cheap composition for moulding mirror frames, rosettes, etc. Glue is also used in the pro-

duction of mosaics, plaques, trays, finger-plates, leather wall coverings, transparent tablets, and in the manufacture of wallpapers, cardboard boxes, millboards, papier-mâché, emery paper, etc. A large quantity of glue is also used by shipbuilders and in the Government dockyards and military arsenals, in the building of battleships and the making of shells.

Cabinetmakers and woodworkers are familiar with the use of glue in dressing tool cuts and other slight wounds incident to their calling. The addition of acetic acid to the glue and a little otto of roses will cover the odour of the glue. This compound, spread on paper or muslin, makes a good substitute for adhesive plaster. It is easily and quickly prepared by placing in a vessel of boiling water a bottle containing 1 part of glue and 2 parts of water; when dissolved add 1 part of acetic acid and a few drops of the perfume. The mixture is kept in a wide-mouthed bottle, well stoppered by a long cork, which can always be removed by heating the neck of the bottle. Care should be taken to keep the mouth of the bottle clean by wiping it with a cloth dipped in hot water.

Gelatine has an extensive use in culinary and confectionery work, although its nutritive value is open to great doubt. So early as 1803 the French Academy, after a lengthy investigation, reported that though gelatine may partially replace flesh in soups, yet it could not be taken as a measure of good value. Many years later (1843) Liebig stated that gelatine, being a product of the decomposition of albumen, could not take the place of that body for food purposes, and this opinion was upheld to a certain extent by Frerichs. Later, Bischoff, in conjunction with Voit, showed that gelatine was only of limited value as a heat-producer, instead of fat and carbohydrates, and that it cannot replace the other nitrogenous constituents of the body. In one respect only

may gelatine claim to have a higher value than albumen, and that is evidenced in the far less time it takes to digest the former than the latter.

A jelly for table use is prepared by soaking 10 parts of gelatine in 8 parts of distilled water for five hours, and then dissolving on the water-bath. To the gelatinous liquor add 1 part of rectified spirit and 1 part of the white of egg, and mix well together. Now heat to boiling to completely coagulate the albumen of the egg, and add 1 part of glycerine, with a few grains of salicylic acid as a preserving agent. Mix the whole ingredients together, and filter, while still hot, through paper moistened with distilled water. The whole should be kept in a chamber heated by steam while filtering.

In the arts gelatine is largely used for many purposes. It has been found of service in the formation of moulds for casting, and one great advantage of the gelatine mould is that casts without seams can be made from them.

In photography a use is made of gelatine in the numerous carbon processes introduced by Johnson, Albert, Swan, and others, in all of which an image is produced by the action of bichromate of potassium on the gelatine used. This is due to the oxidising effect of the chromium compound under the influence of light, which renders the gelatine insoluble in water.

The advantages of rapidity and fidelity in the copying of engineering drawings are well known. The widely used process invented by Poitevin is based on the peculiar property possessed by a ferric salt of rendering gelatine insoluble so long as it is not exposed to the actinic rays. The sensitising solution is composed of 10 parts of ferric chloride and 3 parts of tartaric acid, both dissolved in 100 parts of water. Before the paper is coated with the sensitising solution it is floated on a 6 per cent. solution of gelatine, which is mixed, while warm, with any suitable pigment of the desired colour. On

drying the paper it is ready for use. The sensitising and drying must be carried out in non-actinic light. In using, the paper is placed behind the tracing or drawing, reversed as regards right and left. The time of exposure varies according to the intensity of the light and the thickness of the paper. The gelatine surface which is not covered by the lines of the drawing becomes soluble in hot water on exposure to the light. After the paper is removed from the printing frame, it should be immersed in water at 80° F., when the soluble gelatine will run off the paper.

Few photographers seem to be aware of the immense force exerted by gelatine in its contraction. The property is, however, well known to collotypists, often to their cost. If a collotype plate be overdried, the power of the gelatine is so great that it tears away the surface of the glass itself, breaking it up in peculiar fern-like patterns. The surface of the collotye plate is always ground, and it is that which gives so firm a hold to the gelatine that the glass is torn away. It is a curious fact in connection with the matter, that different grades of gelatine produce a different pattern fracture. A brittle kind of gelatine yields a different pattern from that produced by a tough and horny one. Again, certain salts which are easily crystallised when dissolved in the gelatine influence the nature of the design. For instance, a solution of strong gelatine containing 6 per cent. of alum gave very fine designs, somewhat resembling moss in appearance, and other salts, such as hyposulphite of soda, nitrate of potash, and chloride of potassium, will produce similar forms. This property of gelatine has been taken advantage of commercially in the manufacture of that kind of ornamental glass known as 'crystalline glass,' and largely used for decorative purposes.

In the form of capsules, gelatine is used by druggists to hold many liquids of a greasy nature—castor oil, for instance

—so that they may be swallowed without the unpleasantness arising from their nauseous taste. The capsules are made by the aid of a small egg-shaped, highly-polished, little knob of iron, having a pointed iron stem by which it is held. The knob is rubbed with a slightly oiled cloth, then dipped in a warm gelatinous solution, after which the pointed stem is put into a hole in a board, while the gelatine on the knob is cooling and hardening. The gelatinous solution usually consists of 6 parts of gelatine and 1 part of sugar, both being dissolved in 12 parts of water. In a short time after dipping, the capsule is cold enough to be removed from the mould, which is done by cutting the gelatine round the upper part of the stem with a knife, then pulling off the capsule dexterously with the fingers. At this stage it should be elastic enough to pull off without tearing, and to shrink nearly to the moulded shape directly afterward. A syringe with a nozzle bent at right angles to the axis of its cylinder is used to fill it to about three-fourths of its capacity; if more were forced in, the gelatinous envelope might possibly break afterward with changes of temperature. The hole is closed with a strong solution of gelatine, and the same end of the capsule is then dipped into a weak solution of gelatine to give greater security by the thin cap thus applied. The gelatinous solution used for sealing the capsules always contains a small proportion of gum. On drying the capsules, a polished appearance is given to them by rubbing with a slightly oiled cloth. To protect the capsules from moisture at the ordinary temperature, they are treated, either before or after filling, with a weak solution of alum.

Gelatine is one of the many substances used for the coating of pills, in order that they may not stick together in the box, and may not be tasted in the act of swallowing them. The solution used for coating them consists of 1 part of gelatine dissolved in 2 parts of water. The pills are cleared from any

dust or powder which may be on their surface, then each pill is stuck upon the end of a piece of wire, 4 to 5 inches long, the lower end of the wire being thrust into a basin of sand, which acts as a kind of pincushion. The pills are next dipped, one at a time, into the warm solution of gelatine, then the lower ends of the wires carrying them are replaced in the sand, standing, while their gelatine-coated knobs are setting and drying in the air. Sometimes on removing the pills from the wires a little tube of gelatine from the outside of the wire comes off with it; this tube is carefully cut off with scissors. The hole in the gelatine where the wire pierced the pill is then closed with a little warm solution of gelatine, applied by means of a small brush of camel's-hair. Instead of the customary tin tubes for holding essences, perfumes, etc., Dr Stohr has introduced tubes made of gelatine, which, owing to their transparency, allow of control in the filling. They are said to be cheaper and more durable than metallic tubes. For contents sensitive to light, coloured gelatine tubes are employed.

Owing to the increasing scarcity of the natural product, an artificial ivory is now finding an extensive use, and in the manufacture, gelatine plays an important part. According to a recent process—based on the employment of those materials of which natural ivory is composed, consisting as it does of phosphate and carbonate of calcium, magnesia, alumina, and gelatine—300 parts of lime are first treated with sufficient water to convert it into hydrate, but before it has become completely hydrated or 'slaked,' 75 parts of an aqueous solution of phosphoric acid is poured on to it, and while stirring the mixture 16 parts of ground chalk, 2 parts of magnesia, and 5 parts of alumina are incorporated in small quantities at a time, and lastly, 15 parts of gelatine dissolved in 20 parts of hot water are added. The point to aim at is to obtain a compost sufficiently plastic and as

intimately mixed as possible. It is then set aside to allow the phosphoric acid to complete its action on the carbonate of calcium. The following day, the mixture, while still plastic, is pressed into the desired form in moulds, and dried in a current of air at about 150° C. To complete the preparation of the artificial product, it is kept for three to four weeks, during which time it becomes perfectly hard. In another manufacture, that of artificial leather-making, gelatine is largely consumed. By the process, pure Italian hemp is cut up very fine, and 1 part of this, along with 1½ parts of coarse cleaned wool, are carded together and formed into wadding. This wadding is packed in linen and felted by treatment with hot acid vapours. The resulting product is washed, dried, and impregnated with a mixture whose composition varies according to the leather to be produced. Thus a good sole leather, for instance, is produced in the following manner:—Mix together 50 parts of boiled linseed oil, 20 parts colophony, 25 parts French turpentine, 10 parts of glycerine and 10 parts vegetable wax, and heat over a water-bath with some ammonia water. When the mass has become homogeneous, add 25 parts of gelatine soaked in an equal weight of water, as well as a casein solution, made by dissolving 50 parts of moist, freshly precipitated casein in a saturated solution of 16 parts borax, and adding 10 parts bichromate of potassium. The whole mixture is now boiled until it becomes sticky and the felt is impregnated with it by immersion. The impregnated felt is dried for twenty-four hours at the ordinary temperature, next laid in a solution of acetate of alumina, dried, and finally pressed between hot rollers. Pure Indian ink consists of finely divided carbon cemented together by certain glutinous juices, gum, gelatine, etc. The precise nature of the cement or mucilage used by the Chinese in the manufacture of their inks is not known. But the greater part of the ink now sold as Indian ink con-

sists of fine lampblack and gelatine. Pure fine lampblack is made into a thick paste with a weak solution of gelatine, containing a few drops of musk, and half as much ambergris, the paste then being moulded and dried. Most of the Indian inks met with in commerce possess the disadvantage that they blot when a damp brush is passed over them, or, as draughtsmen say, they do not stand. The addition of alum does little good, but bichromate of potassium accomplishes the object by rendering the gelatine insoluble. The addition does not at all injure the fine shade of colour, as 1 per cent. of it in a very fine powder and intimately mixed with the ink is sufficient. The bichromate must always be mixed with the ink in a dry state, otherwise the latter would lose its friability in water. A drawing which has been made in artificial light by ink containing bichromate of potassium must be exposed to sunlight for a few minutes to render the bichromated gelatine insoluble. In the preparation of roller compositions used by lithographers and printers, gelatine forms the principal ingredient. As manufactured by Hawkins & Stacey, a composition for printers' rollers is made by soaking 16 parts of gelatine in an equal weight of water, and then melting over the water-bath. To the gelatinous solution is gradually added, and then intimately mixed, 24 parts of linseed oil (warmed to 150° F.). To the mixture is then added 20 parts molasses and 1 part dry chloride of calcium, and the whole kept at a temperature of 90° C. for three hours. If a very tough composition is required, a mixture of 2 parts resin dissolved by heat in a little linseed oil, is finally stirred well in the mass. The composition may be made non-absorbent of water, by dispensing with chloride of calcium, and substituting a similar amount of carbonate of bismuth.

In the manufacture of artificial silk under the patents worked by the Vanduara Silk Company, the filaments are

composed entirely of gelatine, specially prepared for the purpose, and forced by strong pressure through fine nipples. The threads are capable of taking on any shade of colour, by immersion in the dye-bath.

In the textile trades, and also in the finishing of white straw hats, considerable quantities of gelatine are used; while in the manufacture of the finer classes of paper it is used as a size. As a substitute for wax, gelatine finds a use in covering the corks and upper part of the necks of bottles.

CHAPTER X.—RESIDUAL PRODUCTS FROM GLUE AND GELATINE.

ALL crops contain certain mineral matters in their ashes. These substances are absorbed from the soil during the growth of the plants. Hence no land can produce crops without deterioration in their fertilising power. To maintain the fertility of the soil by returning to it these ingredients which former crops have exhausted as food, recourse is had to natural or artificial manures which return to the land the necessary phosphates, nitrogen, and potash for the production of vegetable structure. To enrich the soil of this country over 32,000,000 pounds sterling are annually spent in fertilisers, and of this vast sum fully one-sixth is derived from the residual products of the glue and gelatine industry. These products will now be described, along with the uses to which they are put.

Skin Residues.—The residual matters left in the digestion of skins are limited in quantity. They contain no phosphate of lime, and are only of value from the small proportion of gelatinous matter left unexhausted in the vats. They contain nitrogen equivalent to about 3 per cent. of ammonia, and are only of service, when dried, in mixing with bone or mineral superphosphates in the manufacture of nitrogenous manures, for wheat, turnips, hops, etc. The drying is

carried out in a jacketed cylinder horizontally supported by two pedestals; the cylinder has a length of 14 feet and a width of 6 feet. Running the length of the cylinder is a shaft to which are affixed a number of beaters which stir up the mass and equally expose the whole to the heat of the jacket. The steam supplying the jacket is superheated by passing it through a number of coils heated by the waste heat of the steam boiler. After five to six hours' exposure to a temperature of about 400° C., the mass in a dry and friable condition is withdrawn through a door placed at the end of the cylinder, and is ready for mixing in the manure house.

Fish Residues.—Fish residues, after the extraction of the oil and gelatinous matters, and when dried in the jacketed cylinder, are used as a phosphatic nitrogenous manure for cereal and root crops and in floricultural work, especially for roses, chrysanthemums, primulas, cyclamens, and other flowering plants. The necessary potash, as sulphate, is added during the passage of the dried residues through a disintegrator. The finished manure contains—

	Per cent.	Per cent.
Nitrogen, equal to ammonia, .	3·69	3·36
Phosphates (fish-bone), . .	9·14	8·71
Potash (sulphate), . . .	6·25	6·04

The manurial value of dried fish residues is much increased by mixing them with high-grade bone superphosphates of ammonia and potash, yielding a manure containing—

	Per cent.
Soluble phosphates, . . .	12 to 14
Insoluble „ . . .	14 to 16
Ammonia (partly soluble), . .	8 to 10
Potash (as sulphate), . . .	6 to 8

From certain species of fish, the skins are prepared and manufactured into an interesting variety of articles. By

means of numerous complicated processes they are manipulated until they resemble, and would easily be taken for, leather, although of a more glutinous and pliable nature. In one speciality this strange substance is cut into long thin strips and plaited very closely together for whiplashes, and to cover portions of the handles of more expensive whips. Certain kinds of lashes and harness laces are also made from such skins, combining flexibility and toughness.

Bone Residues.—In a degreased and degelatinised form the residual bones hold an important place in the works' production. When air-dried, the following analyses represent their composition, as made by the author:—

	In parts per 100.		
Moisture,	12·18	8 16	10·93
Organic matter,	24·62	26·63	23·73
Phosphate of lime,	53·94	55·30	58·05
Carbonate of lime and magnesium,	6·33	5·48	6·12
Oxide of iron,	trace	·21	·05
Alkaline salts,	1·21	1·85	·49
Sand (silica),	1·64	2·37	·63
	99·92	100·00	100·00
Containing nitrogen,	1·71	1·76	1·42
Equal to ammonia,	2·07	2·13	1·72

Degreased and degelatinised bones are used on the land, either ground to a meal or crushed to a quarter-inch size by a mill. When treated with sulphuric acid, which renders a portion of the phosphate soluble and thus more readily taken up by the growing crops, they form superphosphates. When used alone or in conjunction with mineral superphosphates, they form the basis of special or mixed manures.

Degreased and degelatinised bones naturally contain less nitrogen than raw bones, and consequently are of less value agriculturally, owing to this deficiency. On the other hand, the phosphates are increased and in a condition more readily decomposed in the soil.

They are specially suitable where early results are required.

When ground to a meal, the bones are liable to adulteration, which remains undetected unless by analysis; gypsum and the sweepings from granaries are used for the purpose.

The following analysis by Dr Voelcker shows the low manurial value of a meal adulterated with sulphate of lime (gypsum).

	In parts per 100.
Moisture, ...	3·95
Organic matter with salts of ammonia,	14·40
Phosphate of lime, magnesia, etc., .	40·32
Sulphate of lime, ...	35·42
Alkaline salts, and carbonate of lime,	4·21
Siliceous matter, ...	1·70
	100·00

Bone superphosphate.—Calcium unites with phosphoric acid, forming three distinct compounds, viz.:—

(*a*) Mono-calcium phosphate ($CaH_4P_2O_8$)
(*b*) Bi-calcium phosphate ($Ca_2H_2P_2O_8$)
(*c*) Tri-calcium phosphate ($Ca_3P_2O_8$).

If tri-calcium phosphate, which is an insoluble salt, is acted upon by a combining proportion of sulphuric acid, it is converted into mono-calcium phosphate, the soluble form of phosphate required by the manure-maker. With the discovery of this action by Justus von Liebig originates the well-known superphosphate industry.

The change is represented by the equation:—

Tri-calcium Phosphate.		Sulphuric Acid.		Sulphate of Lime.		Mono-calcium Phosphate.
$Ca_3P_2O_8$	+	$2(H_2SO_4)$	=	$2(CaSO_4)$	+	$CaH_4P_2O_8$
310		196		272		234

From the combining proportions it is seen that 310 parts of insoluble phosphate require for conversion 196 parts of sulphuric acid and yield 234 parts of soluble phosphate mixed with 272 parts of sulphate of lime (gypsum). Supposing that the mineral matter of bones was composed entirely of tri-calcium phosphate, then each cwt. would require for conversion into superphosphate of lime ($CaH_4P_2O_8 + 2CaSO_4$) 0·6322 cwt. of sulphuric acid, the superphosphate containing 53·75 per cent. of mono-calcium phosphate.

These results are never obtained in practical working, owing, in the first instance, to the amount of tri-calcium phosphate in the bones, and secondly, to secure the necessary mechanical condition, only a portion and not the whole of the insoluble phosphate is acted upon, the sulphuric acid being adjusted to effect this purpose. A too perfectly dissolved manure would be damp and pasty, and unworkable in the drills. The presence of carbonate of lime in the bones is of mechanical advantage, insomuch that it renders the superphosphate light and spongy, owing to the carbonic acid liberated during the action.

The following analyses by the author represent the composition of bone superphosphates:—

	In parts per 100.	
Moisture, ...	14·26	15·51
Organic matter, . . .	10·39	11·84
Mono-calcium phosphate, .	21·35	19·66
(=Tri-calcium phosphate made soluble), ...	(28·26)	(26·02)
Carry forward, . .	46·00	47·01

	In parts per 100.	
Brought forward, . .	46·00	47·01
Insoluble or tri-calcium phosphate,	6·48	9·15
Sulphate of iron, . . .	trace	0·08
Sulphate of lime, . . .	42·08	38·53
Sulphate of magnesia, . .	2·35	2·58
Alkaline salts, ...	2·11	1·44
Insoluble matter (silica) . .	0·93	1·21
	99·95	100·00

Bone superphosphate may be made in a small way by mixing in a shallow wooden trough 6 cwt. ground degelatinised bones with one-third their weight of water, and then cautiously adding to the mixture 3 cwts. of brown vitrol (BOV) or 2 cwt. of white vitrol (WOV). Mix thoroughly, and then shovel into a heap, and allow to 'set' for two days. Break up the lumps, pass the whole through a riddle, and finally bag the finished manure.

In working on a large scale, the degelatinised bones, alone, or with a proportion of mineral phosphates, are first crushed and then ground to a fine powder in a mill, raised by an elevator to the dissolving floor of the manure house, and fed into a mixer for treatment with sulphuric acid. The mixer may be of the Morrison type, which is cylindrical in form, the bottom being circular, while the sides are splayed outwards to give good 'boiling up' room. It is built of cast iron flanged plates bolted together, and has a wooden top to which are fixed the acid-supplying pipe, the hopper for charging, and the exit flue for carrying off the gases generated during the mixing. The mixture of phosphates and acid is stirred by a number of cast iron 'beaters' fixed on to a shaft in a spiral form, so that the charge may be forced, when finished, to a discharging door, from whence it falls into a 'den' or brick chamber beneath. In some manure works the mixer is fixed horizontally, and consists of a lead-

lined wooden trough, bevelled at the top, the charging door being part of the bevel. The trough is fed with sulphuric acid from an overhead tank, which is provided with a gauge-glass and scale divided into inches, each inch representing a certain weight of acid—and is well mixed with a charge of 8 to 9 cwts. of degelatinised bones for five minutes, by a spiral arrangement fixed on to a shaft running the length of the trough. At one end of the mixer is placed the discharging door, through which the hot and soft mass is then forced to a brick chamber underneath for cooling and setting. The gases generated during the mixing consist of carbonic acid, with smaller proportions of hydrofluoric and hydrochloric acids intermingled with steam, are carried off by an outlet pipe to a series of flues so arranged with a view to cooling the gases and lowering the tension vapour. On cooling, the steam condenses in the form of moisture, and thus carries down with it the soluble acid gases. In the manufacture of superphosphates the consumption of sulphuric acid depends on the nature and amount of impurities in the raw material used. With mineral phosphates, the impurities, which range from 10 to 20 per cent., consist of carbonate and fluoride of calcium, alumina, and oxide of iron, and require to be neutralised with acid over and above the amount necessary to convert the tri-calcium phosphate into the soluble mono-calcic salt. That this amount is considerable may be seen from the following table, showing the absorption of acid per cwt. of each individual impurity present.

1 cwt. carbonate of lime requires 1·225 cwt. sulphuric acid to form sulphate of lime ($CaSO_4$).

1 cwt. alumina requires 2·854 cwts. sulphuric acid to form sulphate of alumina ($Al_2 3SO_4 . 8H_2O$).

1 cwt. oxide of iron requires 1·8375 cwt. sulphuric acid to form sulphate of iron ($Fe_2 3SO_4$).

1 cwt. fluoride of calcium requires 1·256 cwt. sulphuric acid to form hydrofluoric acid (HF).

In bone phosphates (degelatinised bones) the only appreciable impurity is the carbonate of lime, which varies from 6 to 8 per cent., consequently the acid consumed for their conversion would be less than in the decomposition of mineral phosphates.

Sulphuric acid is manufactured in varying strengths, and is sold to the manure-maker either at a price per ton of given strength or so much per unit or degree as registered by the Twaddell hydrometer at a temperature of 60° F.

The acid found most suitable for dissolving degelatinised bones is the quality known as 'chamber acid,' having a specific gravity of 1·57, equal to a Twaddell strength of 114°, and containing 66 per cent. pure sulphuric acid. With a charge of 9 cwts. of bones and 7 cwts. of acid, renewed every ten minutes, a mixer will produce 30 tons of superphosphates daily, which are ready for removal from the chambers—two of which are necessary for the working of each mixer—every alternate day.

Well-made bone superphosphates are friable and porous, and consist mainly of soluble and insoluble phosphates with sulphate of calcium, thus supplying the land with lime, phosphoric, and sulphuric acids. When kept for a lengthy period before using, the percentage of soluble phosphate gradually decreases, owing to the formation of bi-calcium phosphate by the action of the insoluble phosphate. This change is represented by the following equation:—

Tri-calcium phosphate.		Mono-calcium phosphate.		Bi-calcium phosphate.
$Ca_3P_2O_8$	+	$CaH_4P_2O_8$	=	$2Ca_2H_2P_2O_8$
(Insoluble)		(Soluble)		(Slightly soluble)

The formation of bi-calcium phosphate, which may amount to 3 or 4 per cent. in the space of a few months, is a distinct

loss to the soluble power of a superphosphate, for, owing to its slight solubility, it is but slowly diffused through the soil.

Bone superphosphates are brought into the market containing soluble phosphates ranging from 20 to 26 per cent. tri-calcium phosphate, rendered soluble, the insoluble varying from 6 to 12 per cent.

A small proportion of nitrogen is also present, derived from unexhausted nitrogenous matter left in the degelatinised bones.

When mixed with a small proportion of sulphate of ammonia, bone superphosphates are sold under the name of 'dissolved bones,' containing—

	Per cent.
Soluble phosphate, ...	20 to 22
Insoluble, „	10 to 12
Nitrogen, equivalent to ammonia, .	3 to 4

'Dissolved bone compound' is a superphosphate of lower strength than 'dissolved bones,' and contains—

	Per cent.
Soluble phosphate, ...	16 to 18
Insoluble „	7 to 9
Nitrogen, equivalent to ammonia, .	2 to 3

As a substitute for Peruvian guano, bone superphosphates mixed with sulphate of ammonia contain the following:—

	Per cent.
Soluble phosphate, ...	14 to 16
Insoluble „	6 to 8
Nitrogen, equivalent to ammonia, .	12 to 13

Probably there is no phosphatic manure which deserves so much praise by the farmer as bone superphosphate, and if he wishes to keep abreast of the times and is anxious to grow two blades of grass where only one grew before, to carry a larger head of stock and of better quality, to market more fat cattle, and to produce more milk and of higher standard

quality, he must use high-class superphosphate largely and judiciously.

Nearly all soils are deficient in phosphoric acid, but that deficiency can be supplied in the form of superphosphate, the cheapest source in its most soluble and effective form, and it can be applied with marked advantage to all cultivated crops. Land kept under pasture and grazed with farm stock for a series of years becomes steadily poorer in phosphoric acid (phosphates), because it is carried away in the bones and carcases of animals grazing on it. Pastures where ewe flocks are kept and lambs reared lose much phosphates in the bodies of the young animals, all of which have been taken from the soil; milch cows also carry off large quantities of phosphates in their milk, which contains much of this essential material, while the bones of all young cattle and horses are formed at the expense of phosphoric acid in the soil. Here again superphosphate comes to the rescue, and the effects produced by applications of it are marvellous. These results are seen in the experiments made by Mr Alex. Burr, a leading agriculturist, for the purpose of testing the action of several different manures. He divided two fields of 40 acres each of black stony loam land that had been laid down to grass for two years into four sections, manured with the following:—

Section.	Manure per acre.	Yield per acre.
1, . .	No manure, . . .	10 cwt. hay.
2, . .	Kainite, 5 cwt., . .	15 „ „
3, . .	Basic slag, 5 cwt., . .	15 „ „
4, . .	Superphosphates, 5 cwt., .	19 „ „

In the following year (1900) the same sections (Nos. 2, 3, and 4) were treated as below:—

Section.	Manure per acre.	Yield per acre.
2, . .	Kainite, 5 cwt., . .	28½ cwt. hay.
„ . .	Nitrate of soda, 1 cwt., .	28½ „ „

Section.	Manure per acre.	Yield per acre.
3, . .	Basic slag, 5 cwt., . .	27 cwt. hay.
„ . .	Nitrate of soda, 1 cwt., .	27 „ „
4, . .	Superphosphate, 5 cwt., .	34 „ „
„ . .	Nitrate of soda, 1 cwt., .	34 „ „

The same authority also shows the milk yield of cows, by manuring with superphosphate. In 1899, 150 acres of unmanured meadowland carried 40 cows, yielding 14,400 gallons of milk at 6d. per gallon. In 1901 the same meadowland, after a top-dressing of superphosphate, carried 60 cows, yielding 36,000 gallons of milk at 7d. per gallon, an increase of £685 in the production of milk alone. It will be seen that not only was the quantity of milk increased, but also the quality, as shown by the rise in price and as certified by analysis. A large proportion of superphosphates, whether of bone or mineral origin, is converted into mixed or special manures for certain crops. A mixed manure is not a chemical combination, but a mechanical mixture of certain ingredients required by any particular crop for nutritive purposes. For instance, oats, wheat, rye, and other plants thrive principally on nitrogen obtained from sulphate of ammonia, nitrate of soda, or nitrogenous organic matter, such as dissolved wool, woollen refuse and shoddy, fish refuse, leather-meal, etc. With potatoes, clover, beans, etc., potash is the dominant nutritive agent, and this is supplied as chloride, sulphate, or in the form of kainite containing 23 to 25 per cent. of sulphate of potash; while grass, maize, turnips, and other crops depend on phosphates principally, with minor proportions of nitrogen and potash. Thus knowing the requirements of each particular crop, the manufacturer is able to compound a suitable manure of any desired strength and composition.

Manure makers manufacturing their own superphosphate add the required weight of ingredients to the mass removed

from the 'den' or chamber, and pass the whole through a disintegrator to break any lumps and reduce to a powder.

Manufacturers in a small way of business buy the superphosphate at a price per unit of phosphoric acid made soluble, then add the calculated amounts of nitrogen and potash, and well mix the mass together by turning over two or three times.

The following are special bone manures, made from degreased and degelatinised bones, mixed with 25 per cent. of mineral superphosphate, made from Algerian raw phosphates; each manufacturer has his own standard of strength, and sells at a price accordingly.

(*a*) Turnip manure.

	Per cent.
Soluble phosphates, ...	17 to 20
Insoluble „	8 to 12
Nitrogen, equivalent to ammonia, .	2 to 3
Potash, equivalent to sulphate of potash,	3 to 4

The following mixing forms an excellent manure for turnips and mangels:—

Bone superphosphates (20 per cent. soluble),	10 cwt.
Kainite (24 per cent. sulphate of potash), .	2 „
Sulphate of ammonium, ...	2 „
Common salt, ...	6 „

5 to 6 cwt. of the manure applied per acre.

(*b*) Potato manure.

	Per cent.
Soluble phosphates, ...	18 to 20
Insoluble „	6 to 8
Sulphate of potash, ...	7 to 9
Nitrogen, equivalent to ammonia, .	3 to 4

A mixing for potato manure consists of—

Bone superphosphates (20 per cent. soluble),	12 cwt.
Kainite (24 per cent. sulphate of potash), .	6 „
Sulphate of ammonium, ...	4 „

5 to 6 cwt. applied per acre.

Another mixing is made from—

Degreased and degelatinised bones,	1½ cwt.
Algerian phosphate,	½ „
Leather waste,	¼ „
Shoddy (8 per cent. nitrogen),	½ „
Shoddy (5 „ „)	½ „
Sulphuric acid, 110° Tw.,	2½ „

Of this mixture 14 cwt. are taken and mixed with—

Dried flesh,	4¼ cwt.
Sulphate of ammonia,	1 „
Sulphate of potash,	¾ „

The mass is then passed through a disintegrator. High-class potato manure is made from—

Degreased and degelatinised bones,	1½ cwt.
Florida phosphate,	½ „
Leather waste,	2 „
Shoddy (15 per cent. nitrogen),	¼ „
Sulphuric acid, 110° Tw.,	2¾ „

Of this mixture 15 cwt. are taken and mixed with—

Dried flesh,	2 cwt.
Sulphate of ammonia,	2 „
Sulphate of potash,	½ „
Sud cake (2 per cent. of nitrogen),	½ „

4 to 5 cwt. of the mass is applied per acre.

(*c*) Special manure for grass lands.

	Per cent.
Soluble phosphates,	14 to 18
Insoluble „	4 to 8
Nitrogen, equivalent to ammonia,	3 to 4

(*d*) Special manures for cereal crops.

(1) Wheat manure.

	Per cent.
Soluble phosphates,	16 to 18
Insoluble „	4 to 6
Nitrogen, equivalent to ammonia,	4

Applied 4 to 5 cwt. per acre.

The following mixing has been used with great success by Lawes and Gilbert:—

Sulphate of potash,	200 lbs.
Sulphate of ammonia,	200 „
Sulphate of soda,	100 „
Sulphate of magnesia,	100 „
Bone superphosphates,	400 „

(2) Barley and oat manure.

	Per cent.
Soluble phosphates,	18 to 20
Insoluble „	5 to 7
Nitrogen, equivalent to ammonia,	$3\frac{1}{2}$

(*c*) Pea, bean, and vetch manure.

	Per cent.
Soluble phosphates,	20 to 22
Insoluble „	3 to 4
Nitrogen, equivalent to ammonia,	$3\frac{1}{2}$ to $4\frac{1}{2}$

The quantities used are 4 to 5 cwt. per acre.

(*f*) Sugar-cane manure.

	Per cent.
Soluble phosphates,	20
Insoluble „	$4\frac{1}{2}$
Sulphate of potash,	9
Nitrogen, equivalent to ammonia,	11

Applied 5 cwt. per acre.

(*g*) Special celery and onion manure contains:—

	Per cent.
Soluble phosphates,	14 to 16
Insoluble „	4 to 6
Sulphate of potash,	$3\frac{1}{2}$ to 4
Nitrogen equivalent to ammonia,	3 to $4\frac{1}{2}$

(*h*) A well-balanced and all-round fertiliser, suitable for all kinds of crops, especially mangolds, turnips, swedes, and mustard, contains the following:—

	Per cent.
Soluble phosphates, ...	16
Insoluble „	3
Nitrogen, equivalent to ammonia, . . .	2

(*i*) For all root crops, a useful manure is made by treating degreased and degelatinised bones with sulphuric acid and then mixing with the dried offal from lairages. In a manure of this character the nitrogen is derived from organic and animal matter, and delivers up its store of plant food in a slower manner than when the nitrogen exists in the form of sulphate of ammonia or nitrate of soda, both highly soluble salts, which are liable, when applied, to be washed down into the drains in wet weather. A cheap and yet effective manure of this character contains—

	Per cent.
Soluble phosphates, ...	10 to 12
Insoluble „	3 to 4
Sulphate of potash, ...	½ to 1
Nitrogen, equivalent to ammonia, .	2 to 3

Recovery of Phosphate of Lime.—In the manufacture of gelatine the degreased bones are steeped in a dilute solution of hydrochloric acid, which dissolves out practically the whole of the phosphate of lime of the bones, and the recovery of this substance forms a very important item in the economical working of the factory. To effect this recovery the acid liquors and wash waters are passed through a filter to remove any suspended matter and then run into a number of precipitating vats, and treated with a neutralising base, such as lime in the form of milk of lime, chalk made into a cream, or a solution of calcium sulphydrate, the base being added until the solution is slightly alkaline. If the addition of the neutralising base is stopped while the solution is still acid, the precipitate consists chiefly of bi-calcium phosphate. When the precipitation is completed, the tri-

calcium phosphate, as a white 'sludge,' falls to the bottom; and after washing three or four times with cold water, the washed 'sludge' is pumped to large presses, whence it is freed from a large portion of the water, the cakes inside the filtering chambers retaining only about 10 per cent. On removing the filter plates, which are mounted on deep rectangular bars, the cakes fall on to a travelling band which carries them to a drying room, where they are dried in shallow earthen dishes arranged on racks, the heat being supplied by flues running the length of the room.

Precipitated phosphate forms a valuable manure, and is most suitable for light, sandy soils. As tri-calcium phosphate it is far more soluble in water than the finest ground mineral phosphates.

Precipitated phosphate is also largely used in the manufacture of a substitute for cream of tartar in baking. For this purpose it is ground to a fine state of division, and mixed with sulphuric and phosphoric acid in the following proportions:—

Precipitated phosphate, ...	112 lbs.
Sulphuric acid, ...	91 „
Phosphoric acid, ...	42 „

The pasty mass thus formed is dried by steam heat, ground again to a fine powder, passed through a 60-mesh screen, and then intimately mixed with flour or farina in proportions necessary for the strength of acidity required.

Bone Ash.—After degreasing and degelatinising white bones, the bye-product, when completely burned in a retort or kiln, forms a white-coloured ash, which in its concentrated state contains 75 to 85 per cent. of bone phosphate existing as tri-calcium phosphate. The ash, of which large quantities are imported from South America, is used in the manufacture of high-strength superphosphates. The following analyses

by the author represent the composition of pure and commercial samples of bone-ash:—

	In parts per 100. Pure bone ash.	Commercial bone ash.
Water,	...	3·19
Unconsumed carbon,	·29	2·92
Tri-calcium phosphate,	85·89	72·66
Lime,	5·15	7·11
Magnesia,	3·64	3·39
Oxide of iron,	trace	·35
Carbonic acid,	1·58	1·72
Alkaline salts,	1·39	1·69
Silica,	2·03	6·97
	99·97	100·00

Dissolved bone ash or bone ash superphosphate is prepared in the same way as bone superphosphate, and when well made it should be in a fine, dry, powdery condition. From the high percentage of soluble phosphate, dissolved bone ash forms a valuable manure when applied to cereals and root crops on cold clayey soils.

The following is an analysis by the author of dissolved bone-ash:—

	In parts per 100.
Moisture,	16·39
Unconsumed carbon,	2·62
Mono-calcium phosphate,	29·18
= tri-calcium phosphate rendered soluble	(38·65)
Insoluble or tri-calcium phosphate,	3·16
Sulphates of lime and magnesia,	44·47
Alkaline salts,	1·07
Silica,	3·11
	100·00

Leather Waste.—As previously remarked, leather waste is not used in the manufacture of glue, owing to the want of

a practical method to dissociate the tannin from the gelatine, and leave the latter in a condition available for the glue manufacturer. It is, however, important as a material, rich in nitrogen, to the manure-maker. To make leather into a nitrogenised manure, it is first roasted and then ground to a fine powder in a mill, and afterward treated with superheated steam, which removes the greater part of the tannic acid. On drying it in a jacketed pan, and then passing it through a disintegrator, a meal is produced which, without further treatment, is used by the farmer as a manure.

Leather meal contains a high percentage of nitrogen; this product, however, being in an insoluble form, is not so readily available for plant food as the nitrogen in sulphate of ammonia, nitrate of soda, or in chemically treated leather.

Waste leather to be made available as a quick manure is best treated along with shoddy and raw ground phosphates, with sulphuric acid in the superphosphate mixer, in the following proportions:—

Leather waste, ...	2 cwt.
Florida phosphates, ...	2 „
Shoddy (containing 15 per cent. nitrogen),	$\frac{1}{4}$ „
Sulphuric acid, 110° Tw., . . .	$2\frac{1}{4}$ „

The mixture, which contains nitrogen equal to $2\frac{1}{2}$ per cent. of ammonia, forms a base in the compounding of manures for cereal or root crops.

Leather waste is also used in the manufacture of artificial leather, leather boards, etc. For these purposes, the waste is first steeped in weak lime water, and then ground to a fine powder in a rag engine as used by papermakers. The ground leather is then mixed with about half its weight of good Manila rope, coloured with Venetian red, and is now ready to be made into either leather board or stiffenings for heels and toes of boots and shoes. In another method of

treatment leather scrap is shredded and then mixed with a strong solution of ammonia, which forms a gelatinous mass. It is soluble in water, and has no elasticity until it is mixed with indiarubber dissolved in bisulphide of carbon and well kneaded, when it is rendered waterproof. The kneaded mass is then pressed into moulds.

The use of leather board in the manufacture of boots and shoes is one of the bad features of the business. One kind is used for lapping and for veneering laps. The material is made to look like leather and cut like leather. A thin split of true leather makes a veneer that satisfies the demands of the buffing machine. The best board is made from scrap leather mixed with jute, and is used for counters, heel stiffenings or box toes. When properly treated and manufactured, these counters do good service. When leather board is backed with a leather split and moulded into a stiffening, the product is a union counter. Leather board is also used in the making of chair seats, table tops, etc.

CHAPTER XI.—ANALYSES OF THE RAW AND FINISHED PRODUCTS.

THE chemical laboratory fulfils a very important function in the successful conducting of a large works, and as a guide to the chemist in charge this chapter is devoted to a description of the methods adopted in making the many analyses required of the raw and finished products. The raw materials entering the works may be divided into two classes—hide pieces and rough bones. With the former the examination is solely confined to their glue-yielding capacity, and this is best carried out by making a boiling, under conditions closely approximating to the work on a large scale, with an average sample in a small experimental glue plant, which is an important feature in a well-equipped laboratory, and testing the jelly formed on cooling the liquor by the shot test for tenacity.

Assuming that all the nitrogen present is of a glue-forming nature, this may be estimated by Kjeldahl's process as given below; the result multipled by 5·4 indicates the amount of glue present.

Raw Bones.—Although raw bones are not bought under a guarantee, yet it is advisable to examine each day's delivery for moisture, fatty matter, and nitrogen, and this is made as follows, from a carefully selected and crushed sample:—

(*a*) *Moisture.*—Five grams are weighed out into a porcelain crucible and heated for twelve hours at a temperature of 100° to 105° C. On cooling under the desiccator and re-weighing, the loss of weight represents the moisture.

(*b*) *Fat.*—The fat is estimated by a Soxhlet's extraction apparatus as seen in fig. 25, which consists of a small flask A, extractor B, condenser C. The tube holding the sample has a small opening at the bottom, which is covered with asbestos to prevent any loss of the sample. Before inserting in the extractor, the tube, which must be perfectly dry, is weighed and then three parts filled with the sample. On re-weighing, the difference in weight represents the amount taken. The flask A, which must be thoroughly dry, is weighed and the weight noted. In working the apparatus, the solvent ether is poured in at the top of the condenser until the flask A is about half full, and heat applied to the vessel of water in which the flask is placed. Owing to the boiling point of ether, distillation quickly commences, the low ether vapours passing up through one of the limbs of the extractor into the condenser, and on condensation trickle down on to the bones within the tube, dissolving out the fatty matter. When the syphon overflow is reached, the ether with the fat it has dissolved is syphoned off into the flask below, the ether being again driven off, leaving the fat behind. This is repeated some

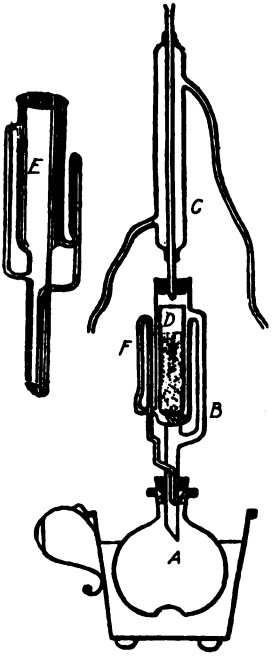


FIG. 25.—Soxhlet's apparatus. Section.

six times, when it may be safely assumed that the bones are denuded of their fat. The flask A is now disconnected, and after wiping is placed in the air-bath and heated for twelve hours at a temperature not exceeding 105° C., this being necessary to drive off any moisture passing over with the ether to the flask. On re-weighing the flask, which is coated with a film of fat, the difference in weight represents the amount of fat in the sample taken. The tube also on removal may be dried for twelve hours at a temperature of 100° to 105° C., and re-weighed; the loss in weight represents the fat and moisture, from which the percentage of the former can be readily calculated.

(*c*) *Nitrogen.*—This is estimated by Kjeldahl's process, which is based on the oxidation of the organic matter, the nitrogen being converted into ammonia, which is fixed by the sulphuric acid present forming sulphate of ammonia, this salt being subsequently decomposed by a solution of caustic soda, and the liberated ammoniacal vapours being absorbed by a standard solution of sulphuric acid. The oxidation is effected in a Jena flask, into which 5 grams of the sample are placed and then covered with 20 c.c. of concentrated sulphuric acid, along with 10 grams of fused bisulphate of potash. The flask is heated on a sand-bath, at first gradually, and as the oxidation proceeds, strongly, for about three hours, when the liquor will have assumed a clear, pale yellow appearance, which indicates the end of the action. On removal of the flask from the sand-bath, it is cooled, and then cautiously filled to the neck with water, stirring well after each addition. The contents of the flask are now washed into a large flask, from which a tube dips under a layer of standard sulphuric acid contained in a small flask kept cool by a stream of water. Connected with the large flask is a funnel with stopcock for conveying a solution of caustic soda, and on applying heat with the Bunsen flame

the ammonia is distilled over and is absorbed by the standard acid. On boiling for an hour, the small receiving flask is disconnected, and the excess of acid remaining is titrated with standard soda solution. Both the acid and soda solutions are of deci-normal strength. From the number of c.cs. of acid uncombined with ammonia is calculated the percentage amount of nitrogen, and this multiplied by 5·4 gives the percentage yield of glue.

Benzene.—In the degreasing of the bones the benzene solvent should be frequently tested so that any diminution in strength may be noted. The testing is carried out by fractionation, and the sample should closely approach the following:—

Boiling point, 100° C.	
Below 100° C. . . .	Nothing
100° to 104° . . .	14 per cent.
104° to 110° . . .	20·5 „
110° to 115° . . .	38 „
115° to 121° . . .	16·5 „
121° to 126° . . .	6 „
126° to 132° . . .	4 „
132° to 138° . . .	1 „
Over 138° . . .	Nothing

Condensed Water.—In running the fat from the benzene plant, the condensed water is daily tested for any loss of gelatinous matter during the degreasing, and the amount, if any, is estimated by the Kjeldahl process.

Degreased Bones.—The degreased bones may retain a portion of fat unextracted during the benzene treatment. This is estimated by the Soxhlet apparatus, as described at p. 109. The loss should not exceed ·5 per cent.

Refined Fat.—Refined fat is sold on a basis of 98 per cent. The impurities generally accompanying the pure fat are—(1) moisture; (2) naphtha; (3) mineral matter; (4) organic matter other than fat. They are estimated as follows:—

(*a*) *Moisture.*—Determined as in (*a*) under the heading of 'Raw Bones.'

(*b*) *Naphtha.*—100 grams of the fat are weighed out and filled into a flask fitted with a cork perforated with three holes. Through one is fixed a thermometer dipping down into the fat Through the second a tube is passed which is in connection with a second flask generating steam, the junction between the two being closed by a clip. Through the third opening a bent tube connected to a Liebig's condenser is passed. To the other end of the condenser is fixed, with rubber tubing, a bent tube dipping under water contained in a flask having a long neck and graduated into $\frac{1}{10}$ c.cs. The flask containing the fat is partly embedded in sand on a sand-bath, and is heated with a Bunsen burner underneath. The heat is raised to about 160° C., which drives over the larger portion of the naphtha present, while the remainder is dispelled by the current of steam which is allowed to play on the fat for half an hour. The vapours are condensed in their passage through the condenser to the receiving flask, and in the latter will be found any naphtha present, floating as a thin film on the surface of the water. On disconnecting the flask and filling with tepid water to about half-way up the neck, then cooling to the normal temperature, the naphtha may be read off in fractions of a c.c., which, when multiplied by the specific gravity, shows the percentage amount present.

(*c*) *Mineral Matter* (*Ash*).—Into a crucible of constant weight 1 gram of the sample is weighed and then slowly incinerated to a black mass. The crucible is now removed to a muffle and heated to redness for ten hours, then cooled under the desiccator, and re-weighed. The increase of weight represents the mineral matter present in 1 gram of the sample; on multiplying by 100 the percentage amount is obtained.

(*d*) *Organic Matter other than Fat.*—This is estimated by treating 2 grams of the sample with ether, stirring well and pouring on to a tared filter, then washing the residue with the same solvent until no trace of fat is visible, when a few drops are evaporated on a watch-glass. The tared filter paper on drying at 100° C. for five hours is re-weighed, and the increase in weight represents the organic matter other than fat in the 2 grams taken.

Glue.—In judging the value of glue many users rely on the colour, smell, and shrinkage. These qualities alone are not a safe guide in forming an opinion, for a glue may have good colour, be free from smell, and well shrunken in the drying, yet at the same time, owing to the deficiency in glutin, the binding power will be low. The higher the percentage of glutin in a glue, the higher is the melting-point of the jelly, and as this is an indication of its strength, it follows that a bone glue in which chondrin is predominant is inferior to a hide glue as a cement. A good glue should be well dried and free from smell; and when immersed in cold water for twenty-four hours it should absorb from nine to eleven times its weight of the water, and when dissolved in hot water to the extent of 11 per cent. the jelly formed on cooling should be firm and consistent, and capable of sustaining a weight varying from 1½ to 2 lbs. Glue should not become damp in ordinary air, or it is liable to turn mouldy, and this fault would indicate impurity or adulteration. Further, in the manner of breaking, a splintery fracture shows that the glue is not well boiled, while judging from the appearance is apt to produce a wrong estimate of its value, for a glue without gloss and very much warped may be excellent in adhesiveness and tenacity. From every batch of glue made a sample cake should be drawn, labelled with a number and date, and kept for future reference, the particulars, along with a record of the testing, being entered in the laboratory journal. A full

examination, whether of a hide or bone glue, comprises—Moisture, ash, water-absorbing power, strength of jelly (shot jelly test), melting point of jelly, capacity for drying, foreign matter, acidity, viscosity, fatty matter, glutin, breaking strain, and foam test. The colour, shrinkage, and smell should also be noted.

(*a*) *Moisture.*—Ordinary glue of good quality contains 14 to 18 per cent. of water; a lower amount indicates over-drying, which injures the tenacity, while a high percentage diminishes the keeping qualities. For determination, a portion of the cake is taken and crushed to a coarse powder in a Wedgwood mortar, and then to a fine meal in an agate mortar. Of the meal 5 grams are weighed in a tared watch-glass, and exposed to a temperature of 110° C. in the air oven for twelve hours. On cooling and weighing, the difference in weight represents the moisture in the 5 grams taken, and from the result obtained the percentage is readily calculated.

(*b*) *Ash.*—In a tared platinum crucible, 5 grams of the powdered glue are weighed, and slowly heated until completely carbonised; the crucible is then transferred to a muffle furnace and heated to a bright redness for ten hours, cooled, and weighed. The increase in weight of the crucible is the amount of ash yielded by the weight of sample taken, and ranges from 2 to 3 per cent. Sometimes sulphate and carbonate of lead, zinc oxide, and the salts of chromium and tungsten are added to the glue before jellying, with the object of increasing its adhesive properties. These ingredients are found in and thus increase the weight of ash. A qualitative examination of the ash will give a clue to the origin of the glue. The ash from bone glue fuses by the heat of the Bunsen flame, and is mainly composed of the phosphates of calcium and magnesium. On the other hand, the ash from a hide glue does not fuse when heated, owing to the presence

of caustic limes derived from the 'liming' of the skins. The ash is also alkaline and free from phosphates.

(*c*) *Water-absorbing power.*—A portion of the sample cake, in one piece, is weighed, and then immersed in cold water having a temperature of 4° C. for twenty-four hours (a very thick cake will require from thirty-six to forty hours). Then carefully remove, drain off all superfluous water, and weigh. The increase in weight is the amount of water taken up mechanically by the glue, and the greater this absorption, the more economical will the agglutinant be found when in use. Fine glue made from white bones will take up from eight to nine times its weight of water, while common German bone glue will only absorb four to five times. In a good hide glue the absorption will reach to eleven times its weight.

(*d*) *Strength of jelly* (shot jelly test), Lipowitz's method.—This test depends on the weight-sustaining power of glue made into a jelly of known strength. The sample made into a solution of 10 per cent. strength is run into a glass cylinder of uniform width to gelatinise. The cylinder, which should be surrounded by a water jacket to maintain a definite temperature, is covered with a cap at one end. The cap is perforated, and through the perforation is passed freely a stout iron wire, at the lower end of which is soldered a piece of tin dipped like a saucer, the convex side resting on the surface of the jelly formed by the cooling of the glue solution. To the upper end is also soldered a similarly shaped piece of tin to hold the weights necessary to force down the wire. The whole apparatus weighs about 10 grams, and is loaded gradually with weights or small shot until the convex side of the saucer-shaped piece of tin is forced into the jelly. The greater the strength of the jelly, the greater will be the weight required. A high-grade glue when made into a jelly will carry as much as 60 grams, while the jelly of a poor quality of glue will sustain only 8 grams.

A commercial form of the above test, known as the 'shot jelly test,' is made by cooling a 10 per cent. solution in an ice-box for three or four hours till firmly set. A tube or small pan is placed on the jelly and loaded with shot till it sinks. The weight of shot used is a measure of the strength of the glue.

(*e*) *Melting-point of jelly.*—Kissling's method, which gives the most satisfactory results, is made under standard conditions. The test is carried out by weighing 15 grams of the sample, and allowing it to stand in 30 c.c. of water for twelve hours in a flask. The solution is then completed by immersing the flask in boiling water and shaking well. While still liquid some of the glue solution is poured into a test tube, which is then closed with a cork. A similar tube is filled to an equal extent with a concentrated (1–1) solution of best hide glue, and a thermometer is inserted in it. These tubes are immersed for an hour in water at 15° C., and are then placed in a bath of special construction. This consists of a round metal water-bath, which is filled to a mark with water maintained at a temperature of 50° C. On to the top of the bath a shallower vessel of equal diameter fits as a lid. The bottom of this is covered with asbestos, and in it are placed horizontally the tubes containing the glues and the thermometer. A plate of glass covers the whole. The melting-point is taken as the point at which the surface of the glue leaves its vertical position and becomes distinctly inclined. The melting-point varies with the amount of glutin present.

(*f*) *Capacity for drying.*—Twenty grams of the sample are dissolved in a little hot water, and then made up to 100 c.c., and the temperature noted. Ten c.c. of the solution are taken, spread on a large watch-glass, and allowed to stand in a room free from dust and not exposed to frequent change of temperature. A standard solution of the same strength

and temperature is made from a high grade of glue, and 10 c.c. of the solution are taken and placed on a watch-glass. The behaviour of the sample jelly is compared with that of the standard during the several days' exposure of the two jellies.

(*g*) *Foreign matter.*—The foreign matter of glue is of an insoluble mineral and organic nature, and is determined by dissolving 5 grams of the sample in hot water and transferring to a glass cylinder holding 1000 c.c., and made up to the litre mark with hot water. The cylinder is immersed in hot water to prevent the solution from congealing. On standing for ten hours, the whole of the insoluble impurities fall to the bottom. The clear liquor is run off and the sediment decanted on to a tared filter, well washed with hot water to remove all trace of glue, and then dried at 105° C. in the air oven. On cooling and weighing, the increase in weight of the tared filter represents the foreign or insoluble matter in the sample taken. The foreign insoluble matter is greater in bone than in hide glues, the latter rarely exceeding 2 per cent.

(*h*) *Acidity.*—Fifty grams of the sample are suspended in a flask in 80 c.c. of cold water for ten hours. The flask is connected with a condenser, and the volatile acids are driven over by a current of steam, the condensed acids and water running into a graduated cylinder. When the distillate amounts to 300 c.c. the distillation is discontinued and the contents of the cylinder titrated with deci-normal alkali. In presence of sulphurous acid, the cylinder should contain a known quantity of the standard alkali, added previous to the distillation. The acidity is due to hydrochloric and sulphurous acids, and the sample should not contain more than ·20 per cent. of these acids.

(*i*) *Viscosity.*—The viscosity of a glue solution of known strength is the length of time taken by the solution to flow

through a burette as compared with water taken at twenty-five seconds in running through the same. The sample of glue is dissolved in hot water to a strength of 1 per cent., and the solution cooled to 18° C., and 50 c.c. run through a burette, the number of seconds required being the viscosity of the solution. The higher the strength of the sample, the greater will be the length of time required for the 50 c.c. of the glue liquor to pass through the orifice of the burette. With a strong glue thirty-two to thirty-four seconds are needed, a medium quality twenty-eight to thirty seconds, while the solution of a weak glue flows through in twenty-six to twenty-seven seconds.

(*j*) *Fatty matter.* — For many industrial applications the small proportion of fat sometimes met with in bone glues is objectionable. The determination is made in the Soxhlet apparatus, as described on page 109, on 5 grams of the powdered glue.

(*k*) *Glutin.*—According to Rideau, the organic matters of glue are very complex. Among the nitrogenous matters to be found in it there are probably several varieties of glutin and chondrin, as analyses of these substances, presumably pure, show differences in elementary composition, in addition to the variation in physical properties. Products of change, such as albumoses and peptones, are usually present, with small quantities of bases, sugars, and ill-defined bodies. For this reason the content of nitrogen and the various processes of precipitation by tannin and other agents, yield results which have but only an approximate relation to the commercial value, for not only is the glutin estimated, but also the peptones and other non-gelatinous nitrogenous matters are thrown down or co-estimated, while the tannates of glutin are too uncertain to make the method thoroughly reliable. These methods may be enumerated as follows (*Trotman and Hackford*):

(1) Determination of total nitrogen by Kjeldahl's process and calculation to glutin.

(2) Determination of total nitrogen by soda-lime.

(3) Precipitation by tannin, and either measuring the nitrogen in the precipitate, or titrating excess of tannin in filtrate.

(4) Precipitation by chlorine and determination of nitrogen in the precipitate.

In the estimation by tannin 10 grams of the sample are weighed (preferably in one piece), and then immersed in cold water for ten hours, the water being changed two or three times to remove any colouring matter in the glue. On dissolving in hot water and pouring into a beaker, the solution is precipitated with tannic acid, forming a dense white precipitate, which, on washing with hot water by decantation three or four times, is then poured on to a tared filter, washed again with a little hot water, and finally dried at 105° C. for ten hours in the air oven. The precipitate of tannate of glutin, when dried, has a composition of

Glutin, ...	42·74 per cent.
Tannin, ...	57·26 „

and from those data is calculated the weight of glutin in the sample taken.

The Bisler-Beaumat method of tannin titration is as follows:—Two solutions are prepared: (*a*) 10 grams of pure tannin are dissolved and the solution made up to a litre; (*b*) 10 grams pure isinglass and 20 grams of alum are dissolved and diluted to a litre. The latter solution is added to a measured quantity of the former till no further precipitate is produced; the volume used is then read off on the burette. The same volume of tannin is then precipitated by a 1 per cent. solution of the glue; the relation between the volumes of the glue solution, and the isinglass, gives the ratio of the glue to the sample of isinglass taken as a standard.

(*l*) *Breaking strain.*—In determining the breaking strain of a glue joint, Bruxchanger devised a sliding or lateral test in which two pieces of red beech a decimetre square were glued together with their fibres parallel and their surfaces overlapping one centimetre. The pieces were fixed in a weeder's testing machine and forced in a direction parallel to their surfaces till the glue yielded and the pieces slid over one another.

Rideau adopts the following method. For the testing blocks a hard, and yet moderately porous, biscuit stoneware is used in place of wood. They are in the shape of a truncated wedge fitting the claws of a glue tester having a system of levers and a weight tub to hold the shot. In making the test, 1 part of glue broken in small pieces is soaked in 2 parts cold water for six hours, then raised to 70° C., agitated until dissolved, and afterward quickly strained through fine muslin. The plane surfaces are then soaked in this solution for half an hour, joined carefully with light pressure, and the pairs mounted in a frame between uprights, each pair being cautiously loaded with a weight of 5 lbs., and the whole kept for five days in a cool and dry room. At the end of that time they are mounted in the testing machine, the utmost care being taken to avoid jerking, to put on the weight gradually, and to keep the lever horizontal. An improvement on the shot would be a hopper with dry sand or mercury flowing through a regulated orifice, with an automatic cut-off at the moment of fracture, which is generally sudden. By this method a high-grade brown Scotch glue gave, with four different pairs of stone blocks, a breaking strain of 675 lbs., 663 lbs., 712 lbs., and 645 lbs. per square inch.

A rough method of determining the breaking strain of a glue, without apparatus, is to cut transversely with a fine saw a stick of wood 1 inch square, to glue the cut surfaces

together, and mount them on end with a moderate weight on top. After three days the bar is laid across the supports and weighted gradually in the middle till fracture ensues.

(*m*) *Foam test.*—In certain classes of work the frothing or foaming of a glue solution is a great disadvantage. It is determined by vigorously stirring for three or four seconds with a glass rod a 10 per cent. solution of the glue, the height of the foam formed measured in inches, and the rate of its disappearance noted. Some glues when in solution show half an inch of foam, others one-eighth, and some none at all.

Gelatine.—When used in confectionery or manufacturing work, gelatine is examined for moisture, ash, water-absorbing power, fatty matter, and acidity, by the processes described under glue.

For testing the purity of a gelatine, Vogel adds ammonia to a 10 per cent. solution of silver nitrate till the precipitate is re-dissolved, and mixes this liquid with an equal volume of the solution of gelatine under examination. If the gelatine is impure, the mixture takes a yellow or even a brown colour.

Degelatinised Bones.—According to the object in view, the degelatinisation for glue may be wholly or only partially carried out. With a carbonising plant at his disposal, the manufacturer extracts only a portion of the nitrogenous carbon as glue, the remainder being left in the bones for animal charcoal.

(*a*) *Wholly degelatinised.*—When the bones are used solely for glue, the examination is confined to nitrogen and phosphate of lime. In preparing the sample for analysis, seven to eight handfuls, representing an average of the whole, are taken and intimately mixed on a sheet of paper, and from this mixture a portion is reduced to a powder by grinding in a mortar.

(*aa*) *Nitrogen.*—The estimation is made by Kjeldahl's method (see 'Raw Bones,' *c.*) on 5 grams of the powdered sample.

(*bb*) Phosphate of lime.—Weigh into a porcelain basin or small beaker 5 grams of the sample, mix with 10 c.c. concentrated hydrochloric acid, and evaporate to dryness on the water-bath to render the silica insoluble.

To the residue add 4 c.c. strong hydrochloric acid, then 20 c.c. water, warm, and then filter off the insoluble silica; wash well with hot water, and in the filtrate precipitate the phosphoric acid by (1) ammonio-citrate of magnesia, or (2) molybdate of ammonium. The solution of ammonio-citrate of magnesia is prepared by dissolving 270 grams of citric acid in hot water, and adding slowly 27 grams of carbonate of magnesia. The heating is continued until the effervescence has ceased and the carbonic acid has been wholly driven off, then filtered into a litre flask, cooled to 15°·5 C., and 400 c.c. of a 10 per cent. solution of ammonia added, the whole being made up to the litre mark with cold water. To the hydrochloric acid filtrate, ammonia is added until strongly alkaline, and then 100 c.c. of the citro-magnesic solution, the contents of the beaker being vigorously stirred until the white precipitate of phosphate of magnesia appears. Allow to stand for six hours, then filter off the precipitate, and wash well with cold water containing 2 per cent. of ammonia. Dry, ignite, and weigh as pyrophosphate of magnesia. On multiplying the weight obtained by 1·3964, the factor for conversion, the result is the weight of tri-calcic phosphate in the sample taken, and from this the percentage is readily calculated.

In using the molybdic method, which is quite as accurate as the citro-magnesic process, the solution of molybdate of ammonium used is prepared by dissolving 1 gram of molybdic acid in 4 grams of ammonia (sp. gr. 0·96), the solution being

slowly poured into 15 grams of nitric acid (sp. gr. 1·20), which must be shaken constantly to prevent separation of molybdic acid. After two days' standing, the clear solution is syphoned off for use. To the hydrochloric acid solution of the phosphates add 10 c.c. nitric acid, and evaporate to dryness. Now add about 6 c.c. nitric acid, and treat the liquid with 150 c.c. of the solution of molybdate of ammonium, and stir well. If the yellow precipitate of phosphate of molybdenum is slow in coming down, add a little ammonia; if too much is used, dissolve any precipitated ferric hydrate formed with a few drops of nitric acid. Allow to stand for eight hours, and then filter. Wash the whole of the precipitate with a mixture prepared by dissolving 15 grams of nitrate of ammonium in 100 c.c. of water, and adding to the solution 5 c.c. strong nitric acid and 10 c.c. of the molybdic solution. When completely washed, the precipitate is dissolved on the filter in dilute warm ammonia. The filtrate is then nearly neutralised with hydrochloric acid, and the phosphoric acid in solution is precipitated with magnesia mixture. After filtering, the precipitate of phosphate of magnesia is washed with a 2 per cent. solution of ammonia, and is finally dried, ignited, and weighed as pyrophosphate of magnesia, the tri-calcic phosphate being calculated as in the citro-magnesic method.

The magnesia mixture is prepared as follows:—Dissolve 83 grams of crystallised sulphate of magnesia in boiling water, add 5 c.c. of hydrochloric acid, and then 82 grams of crystallised chloride of barium previously dissolved in water. Filter off a few drops of this solution and add dilute sulphuric acid; if this gives a precipitate, add a little more sulphate of magnesia. Then decant and filter, mix the filtrate and washings, and concentrate by evaporation on the water-bath. When cool, transfer to a litre flask, add 165 grams of pure chloride of ammonium, 260 c.c. of ammonia, and then

water to the mark. Allow to stand for a few days, and filter if necessary.

(*b*) *Partially degelatinised.*—The object of the manufacturer being charcoal, this product is tested for moisture, carbon, silica, and iron. Animal charcoal possesses the property of absorbing organic colouring matter from solutions brought in contact with it, and this decolorising power depends on the nitrogenous carbon it contains. A good charcoal should contain no more than 11 per cent. of carbon, and no less than 10 per cent. The iron should not exceed ·2 per cent., and the silica ·5 per cent. It is sold on a basis of 8 per cent. of moisture.

(*aa*) Moisture: The moisture is determined as under 'Raw Bones (*a*),' on 3 grams of the powdered sample.

(*bb*) Carbon and silica: Two grams are weighed in a small beaker, and heated for an hour with hydrochloric acid, then filtered through a tared filter paper, the residue left on the filter being well washed with hot water until the filtrate is free from acid. Dry at 105° C. for ten hours, cool, and re-weigh. The increase in weight is the undissolved carbon and silica. To separate the two substances, the filter paper containing the residue is folded up and placed in a tared platinum crucible, slowly carbonised over the Bunsen flame for an hour, and then heated to bright redness in a muffle for ten hours. The carbon is completely burned to carbon dioxide, leaving a residue of silica, along with the ash of the filter paper, in the crucible. Cool and re-weigh. The increase is due to the silica and ash, and on deducting the latter, the former is readily calculated. From the weight of the filter paper *plus* the residue of undissolved carbon and silica the tare of the former is subtracted, and from the net weight obtained the combined percentage of carbon and silica is made. On deducting from this calculation the percentage weight of silica found, the difference is the

percentage amount of carbon in the sample under examination.

(*cc*) Iron: In the acid filtrate from (*bb*) the iron, which exists as ferric chloride, is precipitated in the usual way as hydrate, the precipitate washed with hot water, dried, ignited, and weighed as ferric oxide. From the weight obtained the percentage amount of iron in the sample is calculated.

Manures.—For manurial purposes wholly degelatinised bones are generally converted into superphosphates by treatment with sulphuric acid, which renders a portion of the phosphoric acid soluble. In preparing the different special manures used in agricultural work the superphosphates are mixed with varying proportions of nitrogen (either as organic nitrogen, nitrate of soda, or sulphate of ammonium) and potash salts.

The examination of bone superphosphates is confined to soluble and insoluble phosphates, while in the special or mixed manures the estimation is made of the soluble and insoluble phosphates, nitrogen, and potash.

(*a*) *Soluble phosphates.*—A portion of the average sample taken is ground to a fine state of division in an agate mortar, and 5 grams are weighed out into a porcelain mortar, triturated with a small quantity of cold water, the liquor then passed through a filter paper into a litre flask. The rubbing with water is repeated four times to exhaust the soluble phosphates, and then the contents of the mortar are washed on to the filter paper, and the washing continued until a drop of the filtrate shows no precipitate with molybdic solution The litre flask, which will now be about half full, is made up to the mark with cold water at 15°·5 C., and 100 c.c., representing ·5 gram of the sample, are withdrawn by a pipette for the analysis, which is made by the citro-magnesic or the molybdic method as described under

'Degelatinised Bones' (*bb*). By either method the soluble phosphates are estimated as tri-calcic phosphate.

(*b*) *Insoluble phosphates.*—The residue on the filter paper left from (*a*) is washed into a small beaker with hydrochloric acid, the contents evaporated to dryness on the water-bath, a few drops of hydrochloric acid added and 5 c.c. of water, and the whole filtered to remove the insoluble silica. In the filtrate the insoluble phosphates are estimated by the citro-magnesic or molybdic process as above described. Calculate the result as tri-calcic phosphate.

Nitrogen.—If the nitrogen is derived from added nitrogenous matter, it is estimated in 3 grams of the powdered sample by Kjeldahl's method as given under 'Raw Bones' (*c*). If in the form of sulphate of ammonium, the ammonia is distilled with milk of magnesia in a flask connected to a Liebig's condenser. The distillate is absorbed in 20 c.c. of standard sulphuric acid, and the excess of acid determined by titration with standard soda solution. The ammonia found is calculated to nitrogen. When existing as nitrate of soda, 2 grams of the powdered sample are mixed with 12 grams ignited sand (white). The mixture is placed in a tared platinum crucible and ignited strongly by a foot-blowpipe for twenty minutes. On cooling and re-weighing the crucible, the loss (*minus* the moisture previously determined on the weight of sample) represents nitric acid, from which the percentage of nitrogen is calculated.

The estimation can also be made by Schloesing's method, which is based on the action of ferrous chloride and hydrochloric acid on any solution containing nitrate of soda, the nitric oxide formed being collected and measured in a graduated glass cylinder. From the nitric oxide found, the corresponding amount of nitrogen is calculated.

Potash.—In estimating the potash present in manures, the method adopted by Griffiths yields very accurate results.

Ten grams of the powdered manure are taken and boiled in 300 c.c. of water for ten minutes. Allow to cool, dilute with water to a litre, and filter. Take 100 c.c. of the filtrate (equal to 1 gram of the sample), add 50 c.c. water, and heat to 100° C. Now add, drop by drop with constant stirring, a slight excess of barium chloride, without filtering, and then a solution of barium hydrate, also in slight excess. Heat, filter, and wash the precipitate. Add to the filtrate 1 c.c. of strong ammonia, and then a strong solution of ammonium carbonate, and heat. At this point add ·75 gram of ammonium oxalate, in fine powder. Filter, wash; then evaporate the filtrate to dryness in a platinum basin, and ignite at a low temperature. Digest the residue with hot water. Filter, and wash with the smallest quantity of water possible. Add to this filtrate in a porcelain basin a drop or two of strong hydrochloric acid, and then from 5 to 10 c.c. of platinic chloride solution. Now evaporate on the water-bath to a thick syrup, add a little alcohol of 95 per cent. strength, wash by decantation, collect on a filter, wash with strong alcohol and then with 5 c.c. of ether, dry for half an hour at 100° C., and weigh as potassio-platinic chloride. If any white foreign matter forms in the potassio-platinic precipitate, it must be washed with 10 c.c. of a half-saturated solution of ammonium chloride which has been saturated with potassio-platinic chloride, and finally with alcohol and ether. The precipitate is then dried and weighed.

In estimating the potash, multiply the weight of potassio-platinic chloride found by 0·19308, for chloride of potassium by 0·30627.

Fuel.—The consumption of fuel in the generation of steam, not only for motive purposes, but also for the many operations in which boiling or steaming is a necessity, forms an item of primary importance in the cost of conducting a works. As a matter of economy it then becomes necessary to

examine the heating power of the fuel used from time to time, so that any waste may be avoided.

The heating power of a fuel is found (*a*) by the use of a calorimeter (preferably Thompson's), in which a sample of the coal is burnt and its heating power determined directly from the experiment; (*b*) by estimating the moisture, ash, fixed carbon, and volatile combustible matter.

From these results the corresponding thermal value is calculated, and this, when divided by 966 (the latent heat of steam at 100° C.) gives the equivalent water evaporated from and at 100° C. per pound of combustible used.

When the moisture and ash are low in a fuel, the following simple process for estimating the heating power yields fairly good results. In detail (says Stedman) the process is as follows:—1 gram of the finely powdered coal is intimately mixed with 30 grams of litharge, transferred to a No. 3 Hessian crucible, 20 grams more of the litharge placed on the top of the charge, the crucible covered up and heated to redness in a furnace for fifteen minutes. The crucible is then removed, allowed to cool, broken, and the button of metallic lead cleaned from the slag and carefully weighed.

Duplicate results should not vary more than 0·025 gram. To calculate the result, 1 gram of carbon reduces thirty-four times its weight of lead, and if 1 kilogram of carbon equals 8140 calories, then each gram of lead is equivalent to $\frac{8140}{34}$ = 239 calories. Suppose the lead button from the gram of coal weighed 31·05 grams, then $\frac{8140}{34} \times 31{\cdot}05 = 7420{\cdot}9$ calories per kilogram, or 13357·7 British thermal units (B.T.U.) per pound of fuel, which represents the heating power of the coal.

In practice, the heating value that can be obtained depends on the efficiency of the boiler, and this largely upon the difficulty of thoroughly burning the volatile combustible

matter in the boiler furnace. Supposing the boiler efficiency was 65 per cent., then the evaporation per pound of coal from and at 100° C. would be $14{\cdot}42 \times 0{\cdot}65 = 9{\cdot}37$ lbs.

Note.—A calorie is the standard heat unit, and represents the heat required to raise the temperature of one kilogramme of water from 4° C. to 5° C.

A British thermal unit (B.T.U.) is the heat required to raise the temperature of one pound of water 1° F. at its temperature of maximum density (39°·1 F.).

To reduce calories per kilogramme to B.T.U. per pound, multiply by $\frac{9}{5}$.

Valuation of Raw and Finished Products.

Raw Bones.—Common bones realise from £3 to £3, 5s. per ton. For treatment in the work they are not bought under any guarantee as regards the phosphate of lime or fatty and gelatinous matters they contain. These ingredients vary according to the condition, etc., of the bones; for instance, fresh bones, as ribs, shoulder-blades, heads, etc., will yield 12½ per cent. of fat and 16 to 18 per cent. of glue; but with semi-boiled or kitchen bones which have undergone a partial degreasing and degelatinising, the yield is only from 6 to 8 per cent. of the former and 10 to 12 per cent. of the latter.

For manurial purposes, especially on light soils for turnips and pasture-land, common bones have a use as half-inch bones, quarter-inch bones, and bone-meal. They are sold to the farmer under a guarantee of the phosphate of lime and nitrogen they contain, these ingredients varying from 48 to 50 per cent. and 3½ to 4 per cent. respectively.

Marrow bones, or 'knuckles,' realise from £6 to £6, 5s. per ton, owing to their richness in fat and their value, after a partial degreasing and degelatinising, in the manufacture

of buttons, knife-handles, paper knives, and many other useful articles.

Bone fat is sold at the ruling market price, on a basis of 98 per cent. pure fat; the 2 per cent. of impurities allowed consists of water, ash, and organic matter of a non-fatty nature. Colour being of no importance, dark-coloured benzene-extracted fat is used largely in the manufacture of stearine for candles and glycerine, while the lighter-coloured steam-extracted fat is made into soap, etc.

Tanners' Wastes.—Tanners' wastes, such as the parings of hides, the ears and refuse trimmings of thick hides, yield on an average from 45 to 50 per cent. of glue. They are not bought on any guarantee, but an estimation of their glue-yielding capacity is sometimes made in a small experimental plant consisting of a set of vats with which are connected a filter press, vacuum pan, and drying stove. A determination made in this manner is a safe guide to what the raw materials will yield when worked on the large scale. Gantter, in making a chemical test of the value of tanners' wastes for glue-making, boils 100 grams of the sample with a litre of water and a few drops of soda till completely exhausted, makes up to 2 litres, and allows to stand for ten hours at a temperature above the jellying point of the solution. The insoluble matter settles to the bottom, while any fatty matter forms a film on the surface. The residue and ash are determined in 20 c.c. of the solution, while another 20 c.c. sample diluted with hot water, made neutral with acetic acid and precipitated with tannin, filtered, and any excess of tannin in the filtrate withdrawn by hide powder, dried, and the ash determined, gives the organic non-glue-making material.

Manures.—In the wholesale manure industry, phosphates, whether of bone or mineral origin, nitrogen, as sulphate of ammonia, nitrate of soda, or insoluble nitrogenous matter;

potash, as sulphate, muriate, or as kainite, are purchased at a market price per 'unit,' and this value varies according to the source of the material and its solubility.

If a superphosphate is sold containing 30 per cent. of tri-calcium phosphate rendered soluble by sulphuric acid, it means in the scale of unit values 30 units at the agreed price, and supposing the selling price per unit was 1s. 6d., the value of the superphosphate would be £2, 5s. per ton.

Knowing the unit value of soluble phosphate, nitrogen, and potash, derived from various sources, the way to calculate the money value of a manure is to make its constituents, as given in the analysis, represent 100 tons. The amount of each ingredient is multiplied by its price per ton, and all the products added together give the value of 100 tons. This result divided by 100 gives the value of one ton.

Under clause 1, section 1, ch. 56 & 57 Vict., all manures are guaranteed by analyses, but the seller only guarantees the minimum percentage in each case. In the event of a purchaser desiring an independent analysis of a manure, manufacturers make it a condition of sale that the value of an excess in any one ingredient shall be placed against the value of a deficiency of any other, to the extent of 2 units of either soluble or insoluble phosphate, ½ unit of potash, or ¼ unit of nitrogen.

Manures for analyses are sampled in the presence of buyer and seller or their representatives, within ten days of delivery, the buyer giving three days' notice of his intention to draw samples. In order to arrive at a fair average sample of the bulk, a number of bags (not less than one in every five) are emptied on a clean, dry floor, and the contents well mixed. A quantity of not less than 20 lbs. is then drawn from all parts of the heap, and from this, three glass bottles holding ½ lb. each are filled, sealed, and a label affixed,

giving such particulars as will serve to identify it with the invoice, a copy of which is sent along with the sample for analysis to the chemist. Another of the three samples is given to the seller, and the third is retained for reference in case of dispute. Manufacturers generally accept the analyses of the chemists of the Royal Agricultural Society of England, the Highland and Agricultural Society of Scotland, or the Royal Agricultural Society of Ireland.

APPENDIX.

Selected Specifications of Patents relating to the manufacture of Glue and Gelatine.

English patent No. 18,042, 1902. *Improvements in the manufacture of glue and gelatine*, by Hermann Hilbert, Henfield, Upper Bavaria.

The bones, whether or not they have been degreased and treated for the removal of foreign substances, are mixed with a sufficient quantity of water to form a semi-fluid mass, which is then transferred to a vessel in which the mass may be stirred. There is then added to it hydrochloric acid, or a chloride, and gaseous sulphurous acid while stirring. The chloride may be sodium chloride (common salt) or any other alkaline chloride, and the temperature may be high or low as may be more convenient and suitable. The mass is then macerated and the contained insoluble phosphate of calcium is brought into solution, while at the same time the material is highly bleached. Because of the excess of the sulphurous acid, the phosphate of calcium in the bones becomes decomposed into free phosphoric acid, or double phosphate of calcium and sulphite of calcium, while the chloride is decomposed into hydrochloric acid and sulphite of the alkali. The bone material is consequently affected by two

different acids—hydrochloric and sulphurous acids—simultaneously. The hydrochloric, acting to produce soluble salts, permeates the mass and prepares it for the action of the sulphurous acid, whereby the whole operation is shortened. At the same time the hydrochloric acid acts upon the produced sulphite of calcium and converts it into chloride, sulphurous acid gas is liberated in the nascent state and acts as a powerful bleaching agent, far more effective than simply introducing sulphurous acid either in a liquid or gaseous form. This is the new and important feature claimed by the invention. The glue and gelatine are extracted in the usual way by boiling.

English patent No. 27,053, 1902. *Improvements in the manufacture of glue and gelatine*, by Richard Arens, Ph.D., Ruhrort, Germany.

The methods hitherto employed for extracting phosphate of calcium from bones and the like in the manufacture of glue and gelatine consist in treating the material with dilute hydrochloric acid. The phosphate of calcium is dissolved out, forming monobasic phosphate of calcium and chloride of calcium, and there remains behind the pure cartilage or gristle, which is suitable for further manufacture as a substance capable of yielding glue. The method has the disadvantage that the hydrochloric acid employed is lost in a solution of chloride, and hitherto it has not been possible to employ any suitable means for the recovery. Consequently, for a long time past watery sulphurous acid has been employed in order to free the bone material from the lime salts. The technical difficulties in dissolving with sulphurous acid are, however, considerable. The decomposition proceeds so slowly that even where a very considerable excess of acid is employed, in case it is desired to entirely free the bone from lime, it takes eighty to ninety days to carry out

the operation. The inventor has, however, found that the reasons for the weak action of the acid on the bones is that the sulphurous acid solution, which at its maximum strength contains only 43½ vols. of sulphurous acid gas, in acting on the material, first forms neutral calcium sulphite. This substance is insoluble in water, and is held in solution only by an excess of sulphurous acid, but its solubility ceases as soon as free sulphurous acid present attacks further quantities of the lime, and the monobasic phosphate of calcium commences to saturate the lye. The calcium sulphite is then precipitated, and encrusts the bone material. If then fresh solutions of sulphurous acid be added, the precipitated calcium sulphite must be dissolved in the sulphurous acid. When this has been done, the acid solution can again form fresh quantities of calcium sulphite, and bring into solution acid phosphate of calcium. The point is again reached where the calcium sulphite can no longer be held in solution. It is thus evident that the lye, which contains an excess of free sulphurous acid in large quantities, cannot be strengthened further and no longer acts on the bone material, but diminishes in its strength. By this precipitation of the calcium sulphite and re-dissolving of the same, as already stated, a long time is required for completing the operation, together with an excess of acid, which exceeds the theoretical quantity by 50 per cent. The present process allows of the material being dissolved in a very much shorter time, with a very small apparatus and the theoretical quantity of acid, but the bone material must be treated with sulphurous acid dissolved in water, the liquid being simultaneously subjected to pressure. By this means the sulphurous acid solution is much stronger in the percentage of gas, and the encrustation of the bone material is also avoided, because the lye formed, which is subjected to pressure, has no tendency to crystallise out, owing to the excess of sulphurous acid held in solution,

and because the pressure is capable of holding the calcium sulphite in solution to a greater degree. This process differs from processes already known, in that the phosphate of calcium more particularly is easily and rapidly dissolved out by a cold process, so as to leave behind the glue-forming substance to be extracted in the usual way.

English patent No. 18,742, 1903. *Improved process of rendering or reducing fish waste and other material capable of yielding grease, oil, or glue.*

The primary object of the invention is to extract liquid products from material of the character indicated, rapidly and thoroughly, by heating the material in a closed receptacle and subjecting it during treatment to a pneumatic pressure greater than the pressure which results from the heating of the material, and when the mass has caked or become closely packed to such an extent as to materially retard the flow of oil or extracted product, introducing into the mass air or aeriform liquid under a pressure greater than the first mentioned pressure.

English patent No. 22,069, 1903. *Improvements relating to vegetable gelatine and the process of manufacturing the same,* by Albert Martin, Clinton, Iowa, U.S.A.

This invention relates to a certain new and useful improvement in the manufacture of gelatine from moss. The moss selected is a waste product known as Irish moss, which contains mucilaginous and albuminous matter, as well as cellulose, mineral matter, and water, and is subjected to a treatment which produces a gelatine, or food product, which when used with milk will not coagulate the latter, and hence requires no soda. The moss is thoroughly washed, cleansed from all sand and other impurities, bleached (preferably in

the sun), boiled in water, strained, and the resulting liquid boiled down to a syrupy consistency. The syrup is afterwards spread out upon large pans, and subjected to a gentle heat, whereby large sheets resembling isinglass are produced. This is then shredded. When treated like other gelatine it dissolves readily and gives a superior jelly.

TABLE I.

TESTING OF GLUE AND GELATINE (*Trotman and Hackford*).

Substance.	Pulling Test.	Total Nitrogen.	Nitrogen precipitated by $ZnSO_4$.	Peptonic Nitrogen.
Gelatine No. 1, . .	150	74·03	71·14	1·81
,, ,, 2, . .	144	74·05	71·30	2·67
Glue No. 1, . . .	131	71·8	69·54	2·16
,, ,, 2, . . .	124	74·62	68·03	6·57
,, ,, 3, . . .	112·5	74·50	67·00	7·3
,, ,, 4, . . .	83	71·06	64·18	7·86
,, ,, 5, . . .	37	...	57·99	15·02

The second column gives the physical test, 100 being the standard; the third indicates the total nitrogen; the fourth shows the portion of nitrogen precipitated by zinc sulphate ($ZnSO_4$), which is the true measure of the glue; the last column gives the peptonic nitrogen, which is approximately the difference between the total nitrogen and that precipitated by zinc sulphate.

TABLE II.

VISCOSITY OF GLUE (*Fels*).

Description of Sample.	Moisture per cent.	Time of Efflux of 500 c.c. of a 15 per cent. solution at 30° C., water taking 90 seconds.	Viscosity.
Light-yellow transparent thick plates, . .	16·3	149	1·65
Brown transparent glue,	14	125	1·36
Sherry-coloured transparent glue, . .	15·4	171	1·91
Light-yellow glue plates, brittle, . . .	18·2	150	1·6
Muddy glue, . . .	15·2	199	2·21

The above figures show that a dark and muddy glue may have greater strength than a transparent glue.

TABLE III.

Description.	Price per cwt.	Smell of Soaked Glue.	Viscosity 17 per cent. Solution at 25° C.	Percentage Non-gelatine.
Skin-glue No. 1, . .	44s.	Good	15	7·6
,, ,, 2, . .	44s.	Good	9	8·2
,, ,, 3, . .	48s.	Very good	4	8·3
Bone-glue (powder) No. 1,	36s.	Fair	4·2	...
,, ,, ,, 2,	36s.	Unpleasant	5·5	...
,, ,, ,, 3,	36s.	Fair	3·7	15·0
,, ,, ,, 4,	36s.	Fair	7·4	13·6
Mixed glue, . . .	41s.	Bad	2·8	13·6
Bone-glue in cakes, No. 1,	28s.	Bad	...	...
,, ,, ,, 2,	26s.	Very bad	...	..
,, ,, ,, 3,	26s.	Rather bad	2·8	15·6
,, ,, ,, 4,	26s.	Bad	4·4	8·75

TABLE IV.

Holding Power of Glue Joints (*Kilmarsch*).

Description of Wood.	In Kilograms per Square Centimetre.	
	Cut across the Grain.	Parallel to the Grain.
Beech, ...	155	79
Hornbeam, ...	126·5	79
Maple, ...	88	63
Oak, ...	128	55
Fir, ...	110	24

TABLE V.

Phosphatic Strength of Mineral Phosphates, Bone Ash, and 'Spent' Animal Charcoal.

Description.	Percentage of Tri-calcium Phosphate.
Florida phosphate, ...	76·84
Algerian ,, ...	57·05
Belgian ,, ...	52·01
Bone ash No. 1, ...	88·43
,, (American), . . .	84·65
Lyle's grey char (charcoal), . . .	63·08
Fairie's dark char, ...	69·07
Liverpool spent char, ...	70·24
Greenock char siftings, ...	61·40
Walker's spent char, ...	51·34
Roxburgh ,, ...	64·28

TABLE VI.

Ammoniacal Liquor produced in the Distillation of Bones for Animal Charcoal.

Ounce Strength per Gallon.	Per cent. of Ammonia.	Yield of Ammonium Sulphate per Gallon of Liquor.	Weight of Sulphuric Acid at 144° T. required per Gallon of Liquor in lbs.
18 oz.	3·902	1·513	1·405
19 ,,	4·192	1·597	1·483
20 ,,	4·336	1·68	1·562
22 ,,	4·815	1·84	1·614
24 ,,	5·07	2·00	1·673

TABLE VII.

The Artificial Sources of Gain of Nitrogen in the Soil are by the Use of Artificial Manures. The following Table gives approximately the Supplies of Nitrogen from these Manures (*Griffiths*).

Description.	Percentage of Nitrogen.	Total used per Annum. Tons.	Containing Tons of Nitrogen.
Bones, ...	4	100,000	4,000
Guano, ...	6	30,000	1,800
Sodium nitrate, . . .	15	100,000	15,000
Ammonium sulphate, . .	19	50,000	9,500
Fish guano, ...	8	15,000	1,200
Dried blood, ...	8	15,000	1,200
Shoddy, ...	8	12,000	960
Oil cake and cotton seeds, .	4	500,000	20,000
Total, . . .	...	822,000	53,660

TABLE VIII.

STANDARD SOLUTIONS USED IN THE VOLUMETRIC WORK OF THE LABORATORY.

Standard solutions are prepared of a normal or deci-normal strength as required. The latter are one-tenth the strength of the former.

To prepare—

(*a*) *Normal sodium carbonate.*—Dissolve 53 grams pure dry salt in water and make up to 1 litre at 15°·5 C.

1 c.c. = ·053 gram Na_2CO_3
= ·030 ,, CO_3
= ·022 ,, CO_2

(*b*) *Normal sulphuric acid.*—Dilute 30 c.c. acid of 1·84 sp. gr. to 1 litre of water at 15°·5 C.

1 c.c. = ·049 gram H_2SO_4
= ·040 ,, SO_3

(*c*) *Normal hydrochloric acid.*—Dilute 181 grams pure acid of 1·10 sp. gr. to a litre at 15°·5 C.

1 c.c. = ·0365 gram HCl
= ·0355 ,, Cl

(*d*) *Normal sodium hydrate.*—Take 40 grams of chemically pure or 42 grams ordinary caustic soda, dissolve, and dilute to a litre at 15°·5 C.

1 c.c. = ·040 gram NaHO
= ·023 ,, Na

(*e*) *Deci-normal potassium permanganate.* — Dissolve 3·156 grams pure salt, and dilute to a litre at 15°·5 C.

1 c.c. = ·003156 gram $K_2Mn_2O_8$
= ·0056 ,, Fe
= ·0008 ,, O
17·85 c.c. = ·1 ,, Fe

(*f*) *Deci-normal potassium bichromate.*—Dissolve to a litre at 15°·5 C., 4·913 grams of the dried salt.

1 c.c. = ·0049 gram $K_2Cr_2O_7$
= ·0056 ,, Fe
= ·0072 ,, FeO
= ·00127 ,, I

(*g*) *Deci-normal silver nitrate.*—Dissolve to a litre at 15°·5 C. 17 grams of the pure salt.

1 c.c. = ·0017 gram $AgNO_3$
= ·00355 ,, Cl

(*h*) *Deci-normal sodium thiosulphate.*—Take 24·8 grams of the crystallised salt, and dissolve to 1 litre at 15°·5 C.

1 c.c. = ·0248 gram $Na_2S_2O_35H_2O$
= ·0127 ,, I

(*i*) *Deci-normal sodium chloride.*—Dissolve 5·85 grams of the fused salt in water, and dilute at 15°·5 C. to a litre.

1 c.c. = ·00585 gram NaCl
= ·0108 ,, Ag

(*j*) *Standard solutions for phosphates.*

(*a*) *Uranium nitrate solution :—*
Weigh out 35 grams crystallised uranium nitrate dissolved in 900 c.c. of water and add 25 c.c. glacial acetic acid.

(*b*) *Sodium acetate solution :—*
Dissolve 100 grams of the salt in water, add 100 c.c. of acetic acid, and make up to a litre at 15°·5 C. with water.

(*c*) *Sodium phosphate solution :—*
Take 23·1 grams of pure crystallised salt (previously dried by pressure between filter paper) and dissolve to a litre of water at 15°·5 C.

(*d*) *Solution of potassium ferrocyanide* (freshly prepared), used as the indicator upon a white tile.

Water is added to the uranium solution (*a*) so that 20 c.c. of it are equivalent to 50 c.c. of the phosphate solution (*c*) or

1 c.c. of uranium solution = ·005 gram P_2O_5.

The uranium solution undergoes a change on standing, and should be re-standardised every four or five days.

The principal indicators used in volumetric work are phenolphthalein, phenacetin, eosin, litmus, methyl orange, cochineal, corallin, starch, potassium chromate, potassium ferrocyanide, and ferric chloride.

TABLE IX.

TABLE OF FACTORS FOR DETERMINING THE EQUIVALENTS OF WEIGHED BODIES.

Found.	Wanted.	Factor.
Ammonia (NH_3),	Nitrogen (N),	·8235
	Ammonium sulphate ($(NH_4)_2SO_4$),	7·7649
	Ammonium chloride (NH_4Cl),	3·1470
Barium sulphate ($BaSO_4$),	Barium oxide (BaO),	·6569
	Barium carbonate ($BaCO_3$),	·8456
	Sulphuric anhydride (SO_3),	·0343
Carbonic acid (CO_2),	Calcium carbonate ($CaCO_3$),	2·2727
	Lime (CaO),	1·2727
Ferric oxide (Fe_2O_3),	Iron (Fe),	·7000
Lead sulphate ($PbSO_4$),	Lead oxide (PbO),	·7359
	Lead carbonate ($PbCO_3$),	·8811
	Lead (Pb),	·6831
Magnesium pyrophosphate ($Mg_2P_2O_7$),	Phosphoric anhydride (P_2O_5),	·6351
	Mono-calcic phosphate ($CaH_4P_2O_8$),	1·0540
	Bi-calcic phosphate ($Ca_2H_2P_2O_8$),	1·2254
	Tri-calcic phosphate ($Ca_3P_2O_8$),	1·3964
	Magnesium sulphate ($MgSO_4$),	1·0801
	Magnesium chloride ($MgCl_2$),	·8558
Potassic-platinic chloride (K_2PtCl_6),	Potash (K_2O),	·1935
	Potassium chloride (KCl),	·3062

TABLE X.

Approximate Heating Value of Coals (*Kent*).

Percentage of Carbon in the Coal, dry and free from Ash.	Heating power (B.T.U.) per Pound of Combustible.	Equivalent Water evaporated from and at 212° F. per pound of Combustible.
100	14,500	15·00
97	14,760	15·28
94	15,120	15·65
90	15,480	16·03
87	15,660	16·21
80	15,840	16·40
72	15,660	16·21
68	15,480	16·03
63	15,120	15·65
60	14,580	15·09
57	14,040	14·53
54	13,320	13·79
51	12,600	13·04
50	12,240	12·67

TABLE XI.

Table of Thermometric Degrees.

Centigrade.	Fahrenheit.	Reaumur.
Freezing, 0°	Freezing, 32°	Freezing, 0°
5	41	4
10	50	8
15	59	12
20	68	16
25	77	20
30	86	24
35	95	28
40	104	32
45	113	36
50	122	40
55	131	44
60	140	48
65	149	52
70	158	56
75	167	60
80	176	64
85	185	68
90	194	72
95	203	76
Boiling, 100	Boiling, 212	Boiling, 80

Rules for Conversion.

Fahrenheit to Centigrade, $\frac{5(F.-32)}{9}=C.$

Fahrenheit to Reaumur, $\frac{4(F.-32)}{9}=R.$

Centigrade to Fahrenheit, $\frac{C.\times 9}{5}+32=F.$

Centigrade to Reaumur, $\frac{C.\times 4}{5}=R.$

Reaumur to Fahrenheit, $\frac{R.\times 9}{4}+32=F.$

TABLE XII.

TABLE OF THE METRIC SYSTEM OF WEIGHTS AND MEASURES.

Linear Measures.

The metre is the unit in the metric system of linear measure. It is equal to 39·37 inches. It is multiplied and divided by 10 or some power of 10 for the higher and lower measures of length. Thus:

10 millimetres = 1 centimetre
10 centimetres = 1 decimetre
10 decimetres = 1 metre
10 metres = 1 dekametre
10 dekametres = 1 hectometre
10 hectometres = 1 kilometre.

Or the metric linear measure may be given thus

10 metres = 1 dekametre (dm.)
100 metres = 1 hectometre (hm.)
1000 metres = 1 kilometre (km.)
$\frac{1}{10}$ or ·1 metre = 1 decimetre (dm.)
$\frac{1}{100}$ or ·01 metre = 1 centimetre (cm.)
$\frac{1}{1000}$ or ·001 metre = 1 millimetre (mm.)

Measures of Capacity.

The litre is the unit for measuring the volume of liquids and gases, and is equal to 1·76 pints. The units in use are given as follows:

10 millilitres = 1 centilitre
10 centilitres = 1 decilitre
10 decilitres = 1 litre
10 litres = 1 dekalitre
10 dekalitres = 1 hectolitre
10 hectolitres = 1 kilolitre

A litre is equal to the volume of 1000 cubic centimetres.

System of Weights.

The standard unit is called the gramme or gram. From it the larger and smaller weights are derived as follows:

10 milligrams = 1 centigram
10 centigrams = 1 decigram
10 decigrams = 1 gram
10 grams = 1 dekagram
10 dekagrams = 1 hectogram
10 hectograms = 1 kilogram

A gram is the weight of one cubic centimetre of pure water at 4° C.

Connection between the British and Metric Units.

1 centimetre	= ⅜ inch	1 inch	= 2½ centimetres
1 decimetre	= 4 inches	1 foot	= 3 decimetres
1 metre	= 39·37 inches	1 yard	= $\frac{9}{10}$ metre
1 kilometre	= ⅝ mile	1 mile	= 1⅝ kilometres
1 litre	= 1·76 pints	1 pint	= ½ litre
1 gram	= 15½ grains	1 ounce	= 28·4 grams
1 kilogram	= 2⅕ lbs.	1 lb.	= 453½ grams

Conversion of	Multiplier.
Inches to metres	·025399
Metres to inches	39·37079
Gallons to litres	4·543
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